Minutes of proceedings of the Institution of Civil Engineers

Institution of Civil Engineers (Great Britain)

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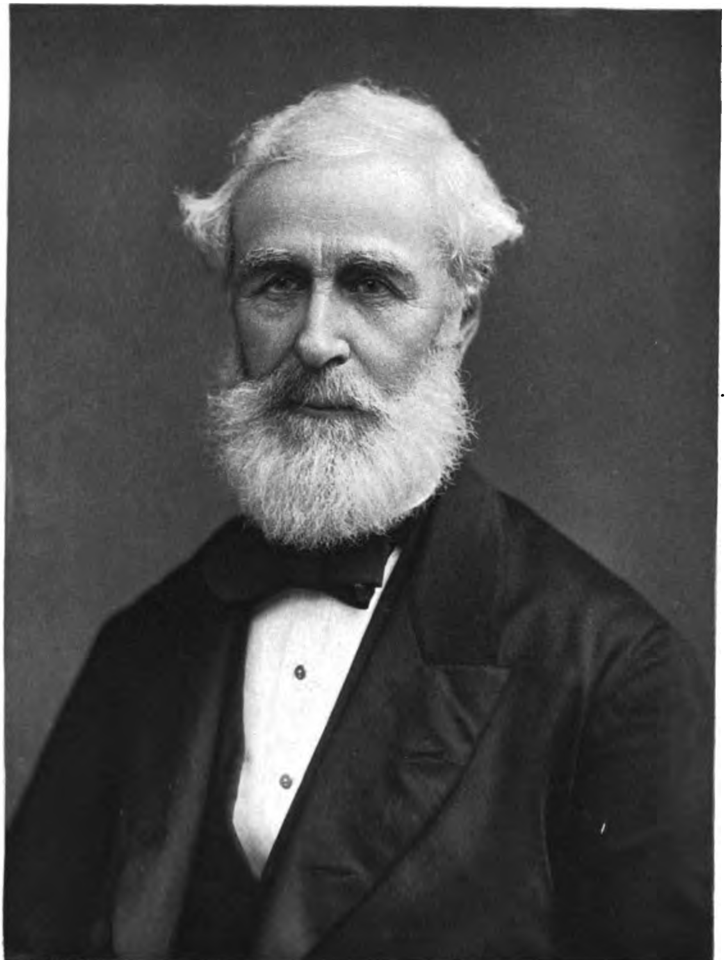

Thos. Kell & Son.

SIR ROBERT RAWLINSON, K.C.B.

BORN 28 FEBRUARY, 1810 — ELECTED PRESIDENT 29 MAY, 1894.

From a Photograph by Thos. Kell, Baker Street.

CIVIL

MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CXIX.

EDITED BY

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CORRIGENDA.

Vol. cxviii. p. 159, line 7 from bottom, *for* "north-east" *read* "north-west."

" p. 389, the statement that "the affairs of this company (Metropolitan) were at that time (1872) in an unsatisfactory condition, its locomotive stock being in a very neglected state" was made on insufficient authority, and is without foundation in fact.

" p. 547, line 12, *for* "J. B. Bruyn" *read* "J. B. Bruun."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1894–95.—PART I.

SECT. I.—MINUTES OF PROCEEDINGS.

13 November, 1894.

SIR ROBERT RAWLINSON, K.C.B., President, in the Chair.

THE Presidential Address of Sir Robert Rawlinson was read, as follows:—

GENTLEMEN,—You have conferred great honour in electing me your President, and so far as health will permit, it is my intention to aid in the advancement and prosperity of the Institution. As this will be the last Presidential Address delivered under this roof, it may be considered appropriate to remind the younger members of the conditions under which their predecessors commenced to build up this great Society. Owing to the building operations we miss to-night from these walls the familiar portraits of those men under whose presidency the Institution has advanced in reputation and in influence from its foundation in 1818. In 1820 it was domiciled at 15 Buckingham Street, Adelphi, where for fourteen years the meetings were held under the presidency of Telford,[1] the first occupant of this chair.

About the year 1834 the Institution removed to No. 1, Cannon Row, within a short distance of this place. Four years later better accommodation was obtained at No. 25, Great George Street; and in the open space at the back of that house, a meeting-room, about 30 feet square, subsequently, in 1846, enlarged to 40 feet by 30 feet, was built on the site of a portion of the theatre in which we are now assembled. For thirty years in that room Papers were read and discussed which will rarely be exceeded in interest during the future of the Institution, and many momentous questions were there virtually decided which have powerfully influenced the practice and the progress of Civil Engineering in this country and abroad.

To meet and anticipate demands for increased accommodation,

[1] Born 1757, died 1834.

the present theatre, which has twice the floor-area of the room that preceded it, was built in 1868, when the library and offices were reconstructed. Although the growth of the Institution since the date last-mentioned has been very considerable, the attendance at the meetings has not increased to such an extent as to require additional seating accommodation. Nevertheless, in consequence of the structural alterations that are to be made, the Session now commencing will be the last in this room, so familiar to several generations of engineers.

During our transition from the old to the new premises some disadvantages will necessarily be experienced in regard to accommodation, both for the meetings and for the other business of the Institution. I, however, do not doubt that the members will share the satisfaction of the Council that the building-operations have been so organized as to permit of our meeting under this roof during the Session, and also enable us to play the part of host to various kindred societies which always meet with a cordial welcome here.

With still more satisfaction I may state that the changes in progress will not be suffered to interfere with the work of publication now carried on by the Institution, nor with the usual facilities for reference afforded by its unrivalled technical library. It may be well to remind the members that they are the possessors of a complete collection of scientific works bearing upon Civil Engineering. There are upwards of 50,000 volumes upon the shelves; and, though some of them may be considered of an ephemeral character, the student may consult in the library every standard treatise upon Engineering, as well as those branches of science whereon its practice is based; whilst the future chronicler of the history of Civil Engineering will find much information available within its walls.

Of the publications of the Institution, there are one hundred and eighteen volumes, containing on an average 500 pages each, in addition to special tracts and published lectures. But is it realised by the members generally that 7,000 copies of every volume are now printed and distributed, and that the "Minutes of Proceedings," with "Other Selected Papers," and "Abstracts of Papers in Foreign Transactions and Periodicals" may be consulted in every civilized country of the world? Each volume records the results of accurate observation, earnest thought and careful criticism bearing upon varied branches of Civil Engineering practice, furnished by men who have given special attention to the subjects dealt with; and this is one of the most important of the courses adopted by the Council "for promoting

an acquisition of that species of knowledge which constitutes the profession of a Civil Engineer," that is, essentially something not military. The Civil Engineer works for peace.

In 1851 the Great Exhibition building, promoted by His Royal Highness the Prince Albert, the iron frame of which was constructed by the late Sir Charles Fox, was opened in Hyde Park, and this event was supposed to be an inauguration of peace among all nations; but within three years, four of the greatest nations in Europe engaged in a desperate and bloody conflict.

The term "Engineer" was for a long period exclusively applied to military men charged with the construction and use of artillery and siege-trains; but works of "Civil Engineering" on a large scale had been executed in ancient times by the Babylonians, Egyptians, Greeks, and Romans. Some of the ruins of those works remain; but many of the greatest examples of ancient masonry have been disintegrated by time or broken by uncivilized hordes of men, massed in armies, marching to rapine and plunder. That which the elements could not destroy, rude men destroyed. A night of savage barbarism brooded over the face of countries once partially civilized. There is, however, little of reliable history for England, after the departure of the Roman legions, until the Conquest.

In the year 1610 a good example of modern civil engineering was commenced by Sir Hugh Myddleton,[1] a goldsmith of Basinghall Street, for the water-supply of a portion of London by bringing in the New River, and this work, by indomitable energy and no mean skill, he subsequently carried to a practical issue. The source of the New River is at Chadwell, from springs rising out of the chalk. The flow from these springs varies betwixt 290 and 700 cubic feet per minute. The length of this New River conduit, as first laid out, was 38 miles; subsequently, by cutting off bends and making other improvements, the length was reduced to 28 miles. The cross-sectional area is about 75 square feet, the gradient 1 in 10,000, and the flow about ½ mile per hour.[2] The channel is in the natural strata unprotected by masonry.[3] The flow is checked by gates,

[1] Born 1555, died 1631.

[2] As the work progressed, Sir Hugh Myddleton found the cost more than he had anticipated, and had to raise an additional sum by the issue of £100 shares, which sank in value as low as £5; and subsequently the value of these shares reached upwards of £90,000 sterling.

[3] In the early days of the New River for supply purposes, the outlet-conduits were of stone, of wood, of earthenware and of cast-iron pipes with flange-joints. The supply-mains now in use in the New River district are of cast-iron pipes with socket joints, and lead pipes, ranging in diameter from 36 inches to 3 inches.

and there are outlet-sluices. The New River is preserved comparatively free from pollution.[1]

Between 1610 and the end of the century the question of building a lighthouse on the Eddystone reef outside the harbour of Plymouth was contemplated. This reef lies in a nearly south-westerly direction about the middle of Plymouth-Sound, and is about 10 miles distant from the nearest land. The rocks and the lighthouse derive their name "Eddystone" from a peculiar current which flows directly contrary to the main stream and so sets up an eddy. These rocks are granite and gneiss, in Cornwall called "moorstone" because they are similar to the surface rocks of some of the moors of the county. Plymouth harbour must have been very dangerous of approach before any lighthouse or breakwater had been constructed, and during the seventeenth century those who had charge of the harbour must have been looking about for an Engineer, the term "Civil Engineer," as regards England, not yet having been invented. However this may have been, the Right Worshipful the Master and Wardens of Trinity House found and nominated Mr. Henry Winstanley of Littlebury, in the county of Essex, to undertake the difficult and dangerous task of erecting a lighthouse on the "Eddystone" reef. We have no information as to the antecedents of this gentleman, and, therefore, can only record that he undertook the task imposed upon him, apparently with a light heart, and proceeded to erect a lighthouse, expressing a hope that during the first great storm he might be in the structure. The work was commenced in 1696 and was completed in 1699. We are not informed whether the Master, Wardens, and assistants of Trinity House were satisfied with the design and construction upon its completion. The work must, however, have been accepted and paid for. On November 26, 1703, Mr. Winstanley, the lighthouse-keepers and some workmen were in the structure when a violent storm occurred, and after so short an existence, the designer, his lighthouse, the lighthouse-keepers and assistants all perished.

One might have expected that the Master and Wardens of

[1] In using the word "purity" in connection with water it may be as well to state that in nature purity is not to be obtained, either in water or in air. The chemist alone obtains some approach to pure elements, which freed from his manipulation rapidly resume their impure state. Water obtained from rivers is more wholesome than that from lakes or reservoirs, as in rivers there is unceasing motion, whilst in lakes and in embanked reservoirs there is comparative stagnation. Populations living on the banks of large rivers use river-water by preference. Rivers polluted by manufactures are exceptional.

Trinity House would have had enough of amateur Engineering; but no! they made a second attempt, and, as England even then could not furnish a "Civil Engineer," they accepted the offer of Mr. John Rudyard, a silk-mercer of Ludgate Hill, who undertook the erection of a second lighthouse on this dangerous rock. The then establishment of Woolwich was, however, to furnish materials and shipwrights. So in the year 1706 Mr. Rudyard and the Government shipwrights commenced a second lighthouse. The structure was built principally of timber, in the shape of a frustum of a cone, 22 feet 8 inches in diameter at the bottom and 14 feet 3 inches at the top, hooped with iron. It is stated that about 270 tons of stone were used in the base of the building. It was finished in 1709, and was repaired several times and seemed to answer its intended purpose; but, in 1755, it was destroyed by fire.

After these disasters the Master, Wardens, and assistants of Trinity House appealed to the Earl of Macclesfield, then President of the Royal Society, to recommend someone to act as Engineer, and he named John Smeaton,[1] a philosophical-instrument maker, to undertake the design and construction of a new lighthouse. Again, a man untrained as an Engineer was the only person who in England could be found to be entrusted with the task of building a third lighthouse on the hitherto fatal rock.[2]

Smeaton was in the North of England when he received the news of his appointment, upon which he communed with himself, and found that he was profoundly ignorant of all that appertained to Civil Engineering, and especially to such a difficult work of masonry as building a lighthouse. He, however, accepted the appointment, and then no doubt studied the designs of the destroyed structures, and examined closely the character of those buildings, thinking over in what way and to what extent they were defective. It has been said that the contour of a graceful growing tree furnished Smeaton with the vertical surface-outline and the circular cross-sectional-form on plan. The elaborate dove-tailing, joggling, and dowelling of each course, stone to stone, and course to course, was, however, no stonemason's work, but was an invention of his own; his aim being to give his lighthouse-pillar cohesive stability, plus gravity. That stability was attained experience has proved,

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[1] Born 1724, died 1792.

[2] As there are full plans, sections, and details of Smeaton's world-renowned lighthouse published, all of which are to be found in the library of the Institution, I do not attempt a description of them. I can only say that the details of the courses of masonry, we must understand, were planned by a mathematical-instrument and chronometer maker, and not by a stonemason.

as his lighthouse remained sound until it was recently taken down, on account of the wear and weakness of the partially disintegrated foundation-rock upon which it was built.[1] It has since been re-erected on the esplanade at Plymouth, where it remains as a monument to Smeaton—the work of a much-valued member of the Institution, Sir James Douglass.

A Fourth Lighthouse.—After an examination of the condition of the rock, a new lighthouse, larger in diameter and taller than the old one, has been erected. In place of having one even vertical contour from the rock to the summit, the base, for 10 or 12 feet above the foundation, is in the form of a drum, with vertical sides. The sea in rough weather and at high tides formerly rose up the sloping surface of Smeaton's lighthouse, and at times even over the lantern, obscuring the light. To prevent this in the future, Sir James Douglass adopted the vertical form at the base, up to and above high water, against which the most violent sea strikes and is reflected back within itself in place of running up the shaft.

The construction of canals and roads about the middle of the last century occupied our earliest Civil Engineers, one of the most notable of whom was James Brindley;[2] and at the commencement of the present century Civil Engineering in Great Britain may be said to have become established as a profession, unaided by Government. Thenceforth to the present time there has been steady progress in great works of Engineering; roads, railways, machinery, bridges, docks and harbours, and as a consequence, in manufactures and in commerce. In France, rivers, canals and roads were and still are under the charge of a Government department. In England, roads were in many cases placed under local trusts and tolls, and toll-houses were established—the taking of tolls being advertised and let to the highest bidder.[3]

The early-formed steam-engine was an imperfect and uneconomical machine, its chief duty being to lift or force water out of mines. James Watt,[4] who served his time as a mathematical instrument maker, improved the steam-engine, and having joined Matthew Boulton, they matured it until it became commercially efficient. James Watt died on the 19th of August, 1819, only ten years before the opening of the Liverpool and Manchester Railway, where George Stephenson[5] demonstrated the adaptability of the steam-engine to locomotive purposes.

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[1] Smeaton commenced his lighthouse on the 12th of June, 1757, and completed it in October, 1759.

[2] Born 1716, died 1792.

[3] Macadam and Telford were, however, employed by the Government of the day on main-road construction.

[4] Born 1736, died 1819.

[5] Born 1781, died 1848.

At some of the Northumberland coal-mines wagon-roads (tramways) of cast-iron plates, and coal-wagons with cast-iron wheels, had been introduced; and these wagons, which ran on the plates, had a gauge of 4 feet 8½ inches, which became the standard for the Liverpool and Manchester line; and that gauge has been followed not only in England, but in many other parts of the world.

The manufacture and manipulation of iron and steel has brought a new class of Engineering into practice. Concrete now takes the place of massive ashlar masonry. The production of steel, while it enriched those who introduced it and greatly reduced the cost of works, is not at present remunerative.

Many forms of rails, chairs, and sleepers have been inverted, which, when tried, were soon superseded. Cross-sleepers of steel or of wood now form the most secure road, and as they can be drawn singly for repairs without stopping the traffic, they make the cheapest as well as the safest form of road. Certain Engineers dictated low gradients to accommodate the poor 11-ton locomotives formerly constructed, and the atmospheric-tube process was taken up by men who ought to have known better; but of all the mistakes then made the worst has been, the neglect to settle by experiment a standard gauge. Experience, however, ultimately settles most things. The Americans are using rails weighing 100 lbs. to the yard, spiked down to sleepers, without chairs. This weight of rail, or probably even a heavier one, may become general. Fishing rail-joints was a simple but most valuable addition.

Improvements in iron and steel have recently made it the practice to construct bridges of spans until recently undreamt of. But I look at London Bridge and Waterloo Bridge, associated with the name of John Rennie,[1] at the Liverpool Docks and the Grosvenor bridge over the Dee at Chester, with undiminished pride. These magnificent specimens of masonry remain, to me, amongst the grandest examples of modern Civil Engineering. I can, however, fully appreciate the mechanical skill and constructive invention displayed in designing and erecting the grand Forth Bridge and the novel Tower Bridge recently opened; but iron and steel bridges, which are exposed to the heat of summer, the frosts of winter, and the oxidising effects of rain and drought, have, when contrasted with bridges of stone, a comparatively short life; and, therefore, I consider that every bridge of steel or iron should be

[1] Born 1761, died 1821.

so designed and so constructed that the entire work may be renewed even whilst traffic is being conveyed over it.

I am not a believer in Engineers being capable of dispensing with the word "impossible." Civil Engineers, in my opinion, are in honour bound to consider safety, endurance, and economy; this has not always been the case, as shareholders have found out.

Sanitary Engineering.

In no branch of Civil Engineering has more remarkable progress been made during the last half-century than in that which is concerned with the health and personal well-being of mankind. During upwards of forty years of my career I have been engaged upon inquiries into the sanitary condition of the cities, towns and villages of England, and also upon works of sewering and draining, and think I may with some authority venture to refer to the progress of sanitary works in general.

Sanitary science is, in a sense, as old as civilization, but it may puzzle a lexicographer to give a satisfactory definition of it. Some learned professor may define physical science and force, but Sanitary Engineering he may reasonably tell us is not a science, and I will not disagree with him. Sanitary science does not necessarily meddle with medicine, nor with surgery, but bases its results on scavenging, town-sewering and house-draining, and on insisting upon all means for the promotion of domestic and personal cleanliness.

As the first Sanitary Engineer ever sent to improve the condition of an army in the field, I may say that larger hospital accommodation and lime-washing, scavenging, more ample ventilation of the Turkish hospitals and better supplies of water proved most effective. I may further indicate what more has been done and at some future time discuss what remains to be done, to place society in a position to escape some of the calamities which have occurred in the past.[1]

---

[1] I may state briefly that the Crimean Army Sanitary Commission consisted of a civil engineer and two medical men. The members landed at Constantinople on the 7th of March, 1855. The mortality in the army and in the hospitals had been greater than any on record. Out of 32,000 troops, 11,000 in the previous three months had died. By the end of the year the entire army in the field before Sebastopol was in better health than it had ever been at home. The English hospitals were almost empty. The French had no sanitary commission, and their great hospitals were full. It was also reported that they had more than 40,000 men down, principally in fever.

The Levitical regulations indicate that leprosy is an outcome of pollution by man, tainted inhabited sites, tainted houses and tainted clothing; and the records published and available of plagues and pestilences are so numerous that they would furnish a library containing accounts of leprosy, black-death, sweating-sickness, plague, and recently influenza and cholera, which have appeared at intervals over the larger inhabited areas of the earth; they are not only commonly recurrent, but ever present, and at this day the empire of China is the seat of ever-recurring plague.

Last year, 1893, and so far in 1894, whilst cholera raged in Russia and on the continent of Europe, Great Britain escaped. Much has been done in England, but much remains to be done. Baths, washhouses, fever-hospitals and gratuitous disinfection, when there is an epidemic of fever, will prevent these diseases from spreading.

In new countries Sanitary Engineering will aim at a general improvement of the uninhabited portions, such as forest-clearing and land-draining, the formation of roads, bridge-building, river improvements, and a judicious selection of sites for towns, villages and houses.

Among the principal of the improvements brought about by the progress of sanitary science, after drainage, water-supply and scavenging, have been the establishment of public baths, wash-houses and disinfecting-apparatus. Some of these establishments have, however, been too grand and costly, as also placed too remote from the poor, and have consequently been failures. Wash-houses and baths for the poor should be situated in the heart of poor districts; their management should be economical; their charges the lowest; and the disinfection of bedding and clothing should be done gratuitously. Any bedding or clothing requiring to be burned should be replaced without charge to the poor afflicted sufferers, this being a charitable act and the truest economy for the ratepayers. Punish a family for having disease and they will shrink from you; treat them kindly and sympathetically, and the poor will respect you.

As British soldiers are costly, it ought to be self-evident that barracks and hospitals which will preserve the men in health should be provided, and this has been done; old barracks have been repaired and new barracks erected. The death-rate in the convict establishment at Portland, under the supervision of the late Sir Joshua Jebb, was only about 3½ per 1,000, when the average

amongst the police was 7 in 1,000, and in the British army 10 in 1,000. Contracts for ration-meat, for clothing, and, above all, for boots and shoes for the Army, should be avoided. To run the risk of being badly served in these things is criminal. England cannot have cheap soldiers, but the army which is best maintained in health will be the cheapest.[1]

It has become usual to credit sanitary works, such as sewerage, drainage and improved supplies of water, with the observed reduction of deaths in the district; and I am not inclined to repudiate this, as I know that good sanitary works do tend to promote comfort, to prevent sickness, and to prolong life. But I also see other powerful influences at work on this great and most interesting problem, namely, education, increase of temperance amongst all classes, better wages to the artisan-workers, shorter hours of labour, cheaper food, cheaper clothing, and a wider-spread sympathy of class with class.

The Condition of the Streets of London.

There is no problem of Sanitary Engineering of vaster range than that presented by this great metropolis. At present the streets of London are crowded to a dangerous excess with sewers, drains, water-pipes, gas-pipes, telegraph and pneumatic tubes, electric-lighting cables and hydraulic-pressure mains. To bring in additional mains of any kind will be found to be impossible without adding to the existing confusion and danger.[2]

No city in this world, of which there is any history, was ever sewered on so great a scale as London now is, and yet the main low-level sewers are too small to relieve the area bordering the river. This has to be remedied by intercepting-sewers and

[1] Some of the results arising out of civil interference in war were to change the heaviest death-rate ever experienced in any former war to a state of health oetter than the army had ever known in barracks at home.

[2] The overcrowded condition of the streets of the business portion of London, both at the surface with crowded traffic and below by various mains and pipes, is at once wasteful of time to trade, dangerous to life and limb and health. New main roads and wider streets are required, and must be formed at whatever cost. This, however, will not be parish work, but Imperial State work. Paris found a man who understood this, and, undertaking the task, performed the work to the great advantage of that city. Is London too poor in wealth, or too poor in statesmanship?

storm-water overflows to the river, so that in its passage through London the river can never be completely purified. There is, however, the consolation that this form of pollution only takes place during seasons of excessive rain, at which times the river is in flood. It has at times occurred to me that deep tunnel sewers in lines irrespective of those of the streets above, may be found necessary to relieve the streets. In Paris there are such large underground tunnels for sewers, gas-pipes, water-pipes, and telegraph tubes and wires.

The sewage of London, now wasted at great cost to the ratepayers, might be taken to the Maplin sands, if these were embanked for the purpose, and on its way be delivered in dressings of liquid sewage over the poor adjoining lands, which would add tenfold to their productiveness, and provide useful employment for casuals, clamouring at the doors of charity, crying out for work every winter. Three steel tubes, each 6 feet in diameter, would convey the sewage from Barking to the sea without nuisance. One tube might first be tried, and if sewage were taken for sewage-irrigation, an income might be earned sufficient to pay the interest on the cost.

The Thames embankment is a grand Metropolitan Improvement spoiled with broken stone. So many thousand tons of broken stone carted on annually; so many thousand tons of mud, when it has done all the mischief possible, to be carted off. Macadam roads in London streets and squares ought to be abolished.

When will water for washing the footways and streets of heavy traffic be secured so that the work may be done before eight o'clock in the morning, the cost for water one penny per 1,000 gallons?

The London Water-Supply Question.

A question of vital importance is that of the present and the future water-supply to the ever-increasing millions who live and work in London.

In 1846 I proposed the area of North Wales as a source from which to draw water for Liverpool and Manchester, and subsequently for Birmingham. The scheme at that time was thought to be too costly. Liverpool now draws water from the head of the River Severn; Manchester brings, for a distance of 90 miles, water from Lake Thirlmere. Glasgow is provided with water from Loch Katrine. Birmingham will presently be supplied from

the hills of Radnorshire. The supply of water to London is still derived mainly from open rivers, the Thames and the Lee.[1]

The River Thames rises in the Cotswold Hills and Bath Oolite formation, at an elevation of 340 feet above Ordnance datum. From its source to London, the river flows generally through meadows very slightly elevated above it—the formations traversed being Oxford clay, chalk and London clay. The dry-weather flow is spring-water. There are no lakes or extensive marshes in which the waters of floods may be stored, to be gradually liberated to equalise the flow of the ordinary stream. The configuration and geological conditions of the Thames basin, which has an area of about 5,162 square miles, tend to render its water singularly pure for so large a river. The jurisdiction over the Thames was in 1866 divided between the Thames Commissioners and the Thames Conservancy Board, the powers of the former body extending from Cricklade to the City Stone above Staines Bridge, and those of the latter body from the City Stone to Yenleete, in Kent.[2]

The River Lee is one of the northern tributaries of the lower Thames. The area of the watershed is about 500 square miles—one-tenth the area of the River Thames. It is tidal from its junction with the Thames to Lee Bridge, for a distance of about 5 miles, and is navigable by barges to Hertford, 28 miles above the Thames.

The important questions are:—Must these sources be continued? must the interests of the Water Companies be bought? and must there then be consolidation of management? If so, under the London County Council, or by a special water trust, similar to the case of the docks at Liverpool and other large trusts? When consolidation has been accomplished, shall the rivers be continued as the main sources of supply for domestic purposes, or shall new sources be obtained? These are wide questions, and will be very costly questions. They, however, require to be answered.

[1] The volume of water supplied to London in the month of May, 1894, was as under:—

	Gallons per day.
From the Thames	108,586,290
From the Lee district	48,942,635
Springs and wells	37,609,439
Hampstead and Highgate	3,802
Total . . .	195,142,166

for a population of 5,457,971, equal to about 35·75 gallons per head per day for all purposes.

[2] A new Board of Conservancy has recently been constituted.

What are the advantages of open river supplies of water for domestic purposes, if any? Open river-water may be termed "living-water," as in both these rivers the sources may be termed pure; remembering that nature does not deal in nor provide pure water for any purpose. The waters of the Thames and Lee may be termed "living," as they are in unceasing motion from their sources, and the strata in both cases are geologically favourable to the supply of "sweet" water. The Conservators of the Thames have, however, allowed the abomination of house-boats to occupy the water and the banks of the river. Regattas bring boats by hundreds and persons by thousands, at stated periods to pollute the water. Bathing in the river is permitted. Steam-launches go at racing speed, raising waves which cut up and waste the banks, and occasionally swamp small boats. The powers of the Conservators have hitherto been insufficient to compel some towns and villages to abstain from polluting the river which provides us with water; but must all these abuses continue? or is there some sort of explanation for their prolonged existence?

The sources of both the Thames and the Lee are as pure, or as free from objection, as it will be possible to find water. The waters are hard; that is, they contain about 16 grains of bicarbonate of lime in each gallon, which may be partially precipitated by boiling. These waters do not act on lead. The existing works are owned and managed by Companies. Consolidation and purchase seem practicable, and then any necessary extensions can be made. To bring in rival Companies, and to attempt to lay additional mains in the already choked streets of London, would be impossible. To bring in soft water from long distances would be costly; additional supplies of water for London may be obtained, in or near the areas through which the Thames and the New River flow.

It is not for me on this occasion to deal in technical detail with the manner in which the evils I have alluded to are to be remedied. Suffice it to say that these questions may well commend themselves to the earnest consideration of some of the six thousand persons to-day borne on the roll of the Institution.

It is almost fifty years since one of my predecessors in this office, Sir John Rennie, on an occasion similar to the present, reviewed exhaustively the history of Engineering up to that time. An epitome of the works and inventions of Civil Engineers during the last half-century would form a worthy sequel to that Address. They have spread a net-work of railways over the British Empire

and its colonies; they have maintained an unrivalled position in ship-building and in the construction of machinery; and with the aid of electricity, by bringing cities and continents into closer communication, they have diminished the circumference of the world.

Mr. ABERNETHY, Past-President, rose and said that so many subjects had been dilated upon by previous Presidents in their addresses, that it became exceedingly difficult for any succeeding holders of the office to select a new subject. Their venerable President, however, had brought before the members an important branch of Engineering with which he had been for a long time well acquainted in his official capacity—that of Sanitary Engineering. It was no doubt a most important subject affecting society generally, and one therefore that could not be too closely considered. The remarks of the President on the subject were extremely valuable, and he had great pleasure in moving, "That a hearty vote of thanks be given to the President for his Address, and that he be requested to allow it to appear in the Minutes of Proceedings."

Sir FREDERICK BRAMWELL, Past-President, said it was his privilege to second the vote of thanks proposed by Mr. Abernethy. He agreed with him that every year it must become more difficult for a President to find an unused subject for his address; but, as he had said when it was his lot to deliver an Address, the profession of engineering was one of so very multifarious a character, that he did not think the time could ever come when the President-elect would be in want of an applicable and an interesting subject. He now repeated this observation, because the Address to which they had just listened was an evidence of its truth. The President had dealt in a concise but in a most comprehensive way with a variety of very important subjects. He had touched upon matters which involved the lives and health of thousands, indeed of millions, and that also involved the expenditure of enormous sums of money, and had thus included two important subjects to which people were never indifferent—their own health and their own pockets. The President had said that he would not enter into the details of the alterations at which he had hinted. He could quite understand that he had refrained from that because the details were of so complex a character that instead of being the subject of a single Address for a brief hour they would require a succession of Papers or lectures to deal with them at all. They had listened to a review of Engineering for

some time past in the particular matter with which the President was the most competent person to deal; and he had done so in an Address which would certainly command the admiration of the members as it had received their deep attention during its delivery.

The motion was carried by acclamation.

Sir Robert Rawlinson, President, expressed his deep gratitude to his old friend, Mr. Abernethy, for the manner in which he had proposed the Resolution; and also to Sir Frederick Bramwell, of whom he could only say that the more he knew of him the more he appreciated him. They had been serving for many years upon the same Council and necessarily saw something of each other. He hoped that the proposer and seconder of the Resolution had not said more with regard to himself than could be justified. He knew how difficult it was for any man thoroughly to understand himself. About the most difficult lesson in the world was for a man to know with any degree of accuracy what he himself was, or had been in his day and generation. He did not mean to say that he should think too much or too egotistically of what he had done, or that he should imagine that it had been given to him to do something that had not been better done before. That he repudiated to the uttermost. He felt that he had on many occasions failed to come up to what he considered he ought to have done. At the same time he had not worked without consideration, for he had thought deeply upon many subjects as they had come before him. He had hoped in his younger days that he should be permitted to serve his country as a civil engineer pure and simple. He had had a similar education to that of the great man who was the virtual founder of the Institution—Telford, who had begun life as a poor boy and a working stonemason. He (Sir R. Rawlinson) began his life as a poor boy and a working stonemason, and he had also worked in each department that he passed through with the thought that if it were possible he would do something better for himself when the opportunity came in his way. [Loud cheers.] An honoured member of the Institution, one whose name he was sure would be received with acclamation, was the man whom he found to be his friend — the son of the inventor of the locomotive and the railway—Robert Stephenson. For four years of his life he served under that great engineer, and he knew that he believed in Robert Stephenson, and that Robert Stephenson believed in him. In almost the middle of his career in 1848 the first Public Health Act ever passed in any nation for the improvement of the health of the people was

passed in England. He was at that time an associate of the Institution, and was the only member of the Institution ever appointed by the Government upon the Sanitary Committee that was then formed. The appointment was offered to him in 1848, and he was very much in the position of Smeaton when he was solicited to undertake the duty of building a lighthouse. He communed with himself and he found that he was profoundly ignorant of everything connected with sanitary science, but he thought that, the duty being once imposed upon him, he should be false to all his principles if he did not, with every power that nature had endowed him with, strive to master the subject that he might not disappoint those who had recommended him to the post. He came to London without friends or acquaintances, so far as he knew. On that Board were Lord Ashley and Lord Morpeth, subsequently to become the Earl of Shaftesbury and the Earl of Carlisle; Mr. Edwin Chadwick was the Secretary. He had sometimes heard the nobility reproached for their pride, and stigmatised as aristocrats. He could only say that if he had been born into the purple he could not have received kinder treatment than he had received at the hands of those two noblemen. If he had been their brother they could not have been kinder to him. They all knew how much depended upon sympathetic kindness, and he hoped that the young men whom he was addressing would never fail to receive that sympathetic kindness from those about them. Money had no value in comparison with sympathy. He would only say, in conclusion, that he had throughout his life bent himself to his work, and, if he did not do all that was expected of him, it was because he could not do any better. It was impossible that he should have striven more than he had striven. From his boyhood he had been a delicate boy, a delicate young man, and he did not know now that he was a very robust old man; but it was astonishing to him that he was able to stand before the members and address them, verging as he was upon his eighty-fifth year. He begged to thank Sir Frederick Bramwell, Mr. Abernethy and the members generally, for their kindness to him. [Loud and continued cheering, amidst which the President resumed his seat.]

The President then distributed the Telford, George Stephenson and Watt Medals, the Telford Premiums and the Miller Scholarship and Prizes awarded by the Council for the Session 1893–94 (vol. cxviii. pp. 304, 305 and 306).

20 November, 1894.

Sir ROBERT RAWLINSON, K.C.B., President, in the Chair.

(*Paper No. 2831.*)

"The Machinery of War-Ships."

By ALBERT JOHN DURSTON, Engineer-in-chief of the Royal Navy.

As the seventy ships ordered under the Naval Defence Act of 1889 have now been practically completed, a few remarks are submitted on the machinery of this Fleet and of those ships fitted with forced draught which preceded it by a few years.

The Tables marked A to E, Appendix, give the names, the I.HP. and air-pressure required to produce the same, the total weight of machinery, the weight of boilers, the fire-grate- and heating-surfaces, and also a brief description of the machinery of the ships fitted with forced draught which preceded those of the Naval Defence Act. First in order (Table A) come seven Battleships, six of the 1st Class and the "Hero" of the 3rd Class. The trials of these vessels were made in 1884–87. The engines are vertical in each case, and the boilers are placed back to back against a middle-line bulkhead, and are fired athwartships.

The six 1st Class Battleships are fitted with vertical three-cylinder compound twin-screw engines, with one high-pressure and two low-pressure cylinders in each set, all of which [1] run at about 100 revolutions per minute with a stroke of 3 feet 9 inches, giving a piston-speed of about 750 feet per minute. All, except the "Anson," are fitted with twelve single-ended three-furnace boilers, with separate combustion-chambers, loaded to 90 lbs. per square inch. The "Anson" has eight single-ended four-furnace boilers, each fitted with two combustion-chambers and loaded to 100 lbs. per square inch.

The "Hero" is fitted with vertical two-cylinder compound twin-screw engines, running at about 110 revolutions with a stroke of

[1] Except those of the "Collingwood," which run at 95 revolutions per minute with a stroke of 3 feet 6 inches, giving a piston-speed of 665 feet per minute.

3 feet, giving a piston-speed of 660 feet per minute. This vessel has eight single-ended three-furnace boilers, loaded to 90 lbs. per square inch, with separate combustion-chambers. The ratio of high- to low-pressure cylinder volumes in all these seven battleships is 1 : 4. The boiler-tubes (see Table A) are of iron, with the exception of those of the "Collingwood," which are of brass. It may be said that since 1881 the use of brass tubes in the Royal Navy for the boilers of large vessels has been practically abandoned.

Next come the 2nd Class Cruisers (Table C), "Mersey" and "Severn," "Thames" and "Forth," trials of which were made in 1885–86. These vessels are fitted with horizontal two-cylinder compound twin-screw engines, running at about 120 revolutions per minute with a stroke of 3 feet 3 inches, giving a piston-speed of 780 feet per minute. They have six three-furnace boilers, of the cylindrical direct-tube type, fitted in a fore-and-aft line, and loaded to 110 lbs. per square inch. With the single exception of those of the "Thames," which have steel tubes, all these boilers have iron tubes. The ratio of cylinders is 1 : 2·8 and 2·9, the size of the low-pressure cylinders being small for the full power. Thus, although not economical at full power, yet at the reduced powers developed on ordinary service a fair ratio of expansion can be used, and in addition there is a certain amount of weight saved —an important item in vessels of this class.

The 3rd Class Cruisers (Table D), "Scout" and "Fearless," have the same type of engines, the revolutions being 150 per minute, the stroke 2 feet 6 inches, and the piston-speed 750 feet per minute. The boilers are of a similar type and four in number, but with the increased pressure, viz. 120 lbs., the ratio of the cylinders is altered to 1 : 3·1.

Next in order of time were the six 3rd Class twin-screw Cruisers of the "Archer" class (Table D) tried in 1886–87. These also are fitted with horizontal compound engines and with four three-furnace boilers of the circular direct-tube type. The pressure was here increased to 130 lbs. per square inch, with a consequent change of cylinder ratio of 1 : 3·4. The revolutions are 150 per minute, the stroke is 2 feet 9 inches, and the piston-speed 825 feet per minute. The "Racoon," tried in 1888-89, has similar boilers, usually described as of the "Navy" type, but is fitted with horizontal triple-expansion engines, the boiler-pressure being 140 lbs. per square inch. These boilers have steel tubes.

In 1887–88 were tested the seven 1st Class belted Cruisers, "Australia," &c. (Table B), fitted with horizontal twin-screw triple-expansion engines, running at 110 to 115 revolutions per

minute, with strokes between 3 feet 6 inches and 3 feet 8 inches, giving piston-speeds of between 770 feet and 840 feet per minute. The ratio of the high- to the low-pressure cylinder is 1:4·8. The boilers are cylindrical, double-ended, with three furnaces at each end. The "Australia" and "Galatea" have one combustion-chamber common to the six furnaces; the remainder have three combustion-chambers, a furnace from each end leading into each chamber. The steam-pressures employed vary between 130 lbs. and 137 lbs. per square inch. These were the first triple-expansion engines fitted in the Navy, and were adopted chiefly at the suggestion of the late Dr. Kirk; although the "Victoria" and "Sans Pareil" had been specified to have triple-expansion engines, but the orders had not been placed. It will be seen from the Table that at this period steel boiler-tubes were becoming more general, and their adoption instead of iron tubes may be dated 1885–86.

In 1889–90, the 1st Class Battleships (Table A) "Nile" and "Trafalgar" were tried. They have vertical twin-screw triple-expansion engines, running at about 95 revolutions per minute, with a stroke of 4 feet 3 inches, giving a piston-speed of about 800 feet per minute. They have six single-ended four-furnace boilers, loaded to 135 lbs. per square inch. Each boiler of the "Nile" has one combustion-chamber, common to the four furnaces, and steel tubes, while each boiler of the "Trafalgar" has two combustion-chambers, two furnaces in each, and iron tubes.

In the heavily-powered Cruisers "Blake" and "Blenheim" (Table B), tested in 1891–92, four sets of engines of the vertical twin-screw triple-expansion type are fitted; two sets driving each shaft, every set being placed in a separate water-tight compartment. The revolutions at full power are 105 per minute, the stroke being 4 feet and the piston-speed 840 feet per minute. The main boilers, six in number, are double-ended with four furnaces at each end. Those of the "Blake" have one combustion-chamber common to the eight furnaces, divided by brickwork into six compartments, the two centre furnaces from the same end leading into one compartment, and the wing furnaces leading separately into the others. The boilers of the "Blenheim" have four combustion-chambers, two contiguous furnaces uniting in each. It will be noticed that the boilers of these two ships form a repetition of those of the "Nile" and "Trafalgar," except that they are double-ended instead of single-ended. The pressure is 155 lbs. per square inch. A small single-ended auxiliary boiler is also provided.

These two 1st Class Cruisers were accompanied in point of time by the "Vulcan" (Table B) Torpedo Depôt-ship, also fitted

with two sets of vertical triple-expansion engines, running at 100 revolutions per minute, with a stroke of 4 feet 3 inches, giving a piston-speed of 850 feet per minute. The boilers, loaded to 155 lbs. per square inch, are similar to those of the "Blake," except that they have three furnaces at each end. A single-ended auxiliary boiler is also fitted as in the "Blake" and "Blenheim," but of larger size, to meet the requirements of the hydraulic boat-lifting appliances.

Going back to the smaller class of vessel, in 1887 the "Medea" and "Medusa" (Table D) were ordered, and were fitted with vertical triple-expansion engines. They were tested in 1888–89. The revolutions are about 140 per minute, the stroke is 3 feet 3 inches, and the piston-speed is 910 feet per minute. The boilers are four in number, double-ended, with three furnaces at each end, and one combustion-chamber common to the six furnaces. They were fitted with iron tubes, and work at a pressure of 155 lbs. per square inch. The combustion-chambers are divided by brickwork into six separate parts.

These were followed in the same year by the "Marathon," "Magicienne" and "Melpomene" (Table D), tested in 1889, which have the last horizontal engines of importance fitted in the Navy. They have twin-screws, triple-expansion engines and four double-ended boilers with three furnaces at each end. There are three combustion-chambers to each boiler, one furnace from each end leading into the same chamber. The revolutions are about 140 per minute, the stroke is 3 feet, and the piston-speed is 840 feet per minute. The steam-pressure is 155 lbs. per square inch.

About a year later five 3rd Class Cruisers were ordered for the protection of the floating trade in Australian waters (Table D), and were tried in 1890. In these vessels vertical engines are fitted as in all subsequent ships. The piston-speed is lower than that in the preceding vessels, ranging from 800 to 815 feet per minute, the stroke being 2 feet 9 inches. There are four double-ended boilers with two furnaces at each end, and with one combustion-chamber common to all four furnaces. In 1890 the four smaller 3rd Class Cruisers, "Barrosa," &c., were tested, having engines and boilers of the same type, but with only two instead of four boilers.

In 1888, the 3rd Class Special-Service Cruisers, "Barham" and "Bellona" (Table D), were ordered. In these vessels, to obtain the high power required with a limited weight of machinery, a modified type of torpedo-boat engine with locomotive-boilers was employed. The engines have a stroke of 2 feet 3 inches and run at 220 revolutions per minute, the piston-speed being 875 feet per

minute. The boilers are six in number, and are wet-bottomed with a single fire-box.

Previous to this another type of vessel had been initiated, known as the "Torpedo Gunboat" (Table E). The first example of this class was the "Rattlesnake," tested in 1887. These vessels are fitted with vertical triple-expansion engines of torpedo-boat type, and with four wet-bottomed locomotive-boilers. The fire-box of the "Rattlesnake" is almost completely divided by flat water-legs into two fire-boxes. The other three vessels of this class are the "Grasshopper," the "Sandfly" and the "Spider," which were tested in 1889. The boilers of the latter two are like those of the "Rattlesnake," but have an undivided fire-box, whilst those of the "Grasshopper" are a modification of the type known as "pinnace" boilers. The engines have the same stroke as those of the "Rattlesnake," viz., 1 foot 6 inches, but they make 300 revolutions, those of the latter being 310 per minute. The piston-speed is thus 900 feet against 940 feet per minute in the "Rattlesnake." The steam-pressures employed are: "Rattlesnake" 140 lbs., "Sandfly" and "Spider" 145 lbs., and "Grasshopper" 150 lbs. per square inch.

The "Sharpshooter" class, tested in 1889–90, are larger and more powerful, the stroke being increased to 1 foot 9 inches, but the revolutions are only 250 per minute, giving a piston-speed of 875 feet per minute. The wet-bottomed locomotive-boiler is used in all of the eleven vessels of this class. The number of boilers is four and each fire-box is undivided.

This completes a brief description of the most important ships fitted with forced-draught added to the Navy in the few years immediately preceding the date of the Naval Defence Act.

The seventy vessels built under the Naval Defence Act of 1889, consist of ten 1st Class Battleships, nine 1st Class Cruisers, twenty-nine 2nd Class Cruisers, four 3rd Class Cruisers, and eighteen Torpedo Gunboats. Of the hulls thirty-two were built by contract, and thirty-eight in the Royal dockyards. Of the machinery, that for sixty-three vessels was supplied by contract, and that for seven, consisting of three 2nd Class Cruisers, one 3rd Class Cruiser, and three Torpedo Gunboats, was built in the Royal dockyards.[1]

The battleships (Figs. 1 and 2, Plate 1, and Table A, vessels bracketed A) have engines of the vertical three-cylinder triple-

[1] Particulars of the trials &c. of these vessels have been recently published in *Engineering*, 23 November, 1894, p. 677.

expansion type, the ratio of the volumes of the high- to the low-pressure cylinders being 1 : 4·84. The revolutions at the full power for which the engines are designed, viz., 13,000 I.HP., are 108 per minute, the stroke being 4 feet 3 inches, giving a maximum piston-speed of 918 feet per minute. Having in view, however, the ordinary rates of steaming, when only a small portion of the full power is developed, it was deemed advisable to arrange the valve-gear for a maximum of 11,000 I.HP. while keeping up the maximum speeds for which the engines were designed; and most of the vessels, as will be seen from the Table, carried out their full-power trials arranged in this manner. The "Royal Sovereign," however, was tried as originally designed, and developed the 13,000 I.HP. specified. The natural-draught power is 9,000 I.HP. The boilers in these vessels are eight in number, of the single-ended return-tube type, having four furnaces in each, uniting in two, three, or four separate combustion-chambers.[1] These boilers, two in each watertight compartment, are placed with their backs towards the longitudinal division, and are stoked from the wings.

In the two battleships bracketed B, the cylinder ratio is 1 : 5·37, while the piston-speed at full power—13,000 I.HP.—is reduced to 840 feet per minute. The natural-draught power is 9,000 I.HP. The boilers are generally of the same description, and are similarly arranged. In the "Barfleur" and "Centurion," each pair of furnaces is led into a common combustion-chamber.

In the 1st Class Cruisers, the engines of the three-cylinder vertical triple-expansion type are arranged abreast in separate watertight compartments, divided longitudinally by a bulkhead (Figs. 5 and 6, Plate 2, and Table B). The boilers are arranged with stokeholds athwartships, separated from each other and from the engine-rooms by transverse coal-blocks. The dimensions of the cylinders are identical with those of the battleships (except the "Barfleur" and "Centurion"), so that the ratio of cylinder volumes, high- to low-pressure, is 1 : 4·84; but the revolutions at the full power—12,000 I.HP.—are only 100 per minute. This, with a stroke of 4 feet 3 inches, gives a piston-speed of 850 feet per minute. As in the battleships, the propellers and valve-gear, in all except the "Edgar," "Hawke," and "Grafton," were subsequently arranged for a maximum power

[1] The "Hood," "Empress of India," "Repulse," "Royal Sovereign" and "Ramillies," have one combustion-chamber to each pair of furnaces. The "Royal Oak" has a separate combustion-chamber to each wing-furnace, the two middle furnaces uniting in a common combustion-chamber. In the "Resolution" and the "Revenge," each furnace has a separate combustion-chamber.

of 10,000 I.HP.—the natural-draught power in this instance—so as to enable them to steam more economically at the low powers usual when cruising. The "Edgar," "Hawke," and "Grafton" made their full-power trials at the powers for which they were originally designed, and satisfactorily developed these powers. In the vessels tried at the lower powers, as well as in the battleships similarly dealt with in this respect, the higher power could at any time be developed by suitable modifications in the valve-gearing and propellers. The vessels bracketed C have four double-ended eight-furnace boilers, and one single-ended boiler for auxiliary purposes, placed in a recess at the forward end of the forward stokehold. Those bracketed D have eight single-ended four-furnace boilers. The furnaces are similarly arranged with respect to the combustion-chambers in all the main boilers of these vessels, *i.e.*, two contiguous furnaces unite in a common combustion-chamber.

Passing to the twenty-nine 2nd Class Cruisers, the machinery and armour-protection in these is arranged similarly to that in the 1st Class Cruisers (Figs. 7 and 8, Plate 2, and Table C). The engines are of the vertical three-cylinder triple-expansion type, the ratio of cylinder volumes being 1 : 4·88 in those bracketed E, and 1 : 5·03 in the remainder. The revolutions at the full power for which these engines are designed—viz., 9,000 I.HP.—are 140 per minute, the stroke being 3 feet 3 inches, giving a piston-speed of 910 feet per minute. The natural-draught power of these vessels is 7,000 I.HP. The vessels bracketed E, as also the "Æolus" and the "Brilliant," have three double-ended boilers and two single-ended boilers, with six and three furnaces in each respectively. The object of substituting two single-ended boilers for one double-ended is to provide boilers of suitable dimensions for auxiliary purposes. In the remaining vessels of this class eight single-ended three-furnace boilers are fitted. This subdivision of the boilers has certain advantages, which are considered to more than compensate for the additional weight involved, viz., absence of leaky shell-joints, which occur in the long boilers by the racking strains set up; the ability to divide the boilers more nearly in the proportion of the power required to be developed; and, further, the spreading of the wear due to steaming for auxiliary purposes over the whole of the boilers rather than confining it to one or two of them.

In the four 3rd Class Cruisers (end of Table D) a similar arrangement of machinery is preserved to that in the 1st and 2nd Class Cruisers, except that, for the transverse coal-blocks separating

the compartments, watertight divisional bulkheads are substituted. The engines are of the vertical three-cylinder triple-expansion type, having a ratio of cylinders, high- to low-pressure, of 1 : 4·97. At the full power for which the engines are designed—7,500 I.HP. —the revolutions are 160 per minute, the stroke being 2 feet 9 inches, giving a piston-speed of 880 feet per minute. The natural-draught power is 4,500 I.HP. They are fitted with four double-ended boilers, having two furnaces at each end, and a separate combustion-chamber to each furnace.

In the Torpedo Gunboats (Figs. 3, Plate 1, and Table E) the engines are arranged as in the Cruisers, viz., abreast in watertight compartments divided by a middle-line bulkhead, while the boilers are arranged with stokeholds athwartships in two watertight compartments, which in those bracketed F are situated forward of the engines. In those bracketed G, the two stokehold compartments are placed one forward and one aft of the engines, an arrangement which facilitates supervision and reduces vibration. The engines are of the three-cylinder triple-expansion type, with a cylinder-ratio of 1 : 5·37. The revolutions at full power, 3,500 I.HP. ("Speedy," 4,500 I.HP.) are 250 per minute, and the stroke is 1 foot 9 inches, the piston-speed being 875 feet per minute. The natural-draught power is 2,500 I.HP. The boilers in all these vessels, except the "Speedy," are of the locomotive wet-bottomed type, four in number, having (except in the "Gossamer") the furnace divided in the middle by a water-division. In the "Gossamer" no such water-division exists, the boilers being similar to those of this class built prior to the Naval Defence Act. In the "Speedy" (Figs. 4, Plate 1) eight "Thornycroft" water-tube boilers are fitted, four in each compartment, arranged two abreast, with the stokehold dividing them.

The general characteristics of the machinery of the vessels built under the Naval Defence Act having been briefly described, a few comparative remarks may be of interest. As regards steam-pressure, it was not considered advantageous to exceed 155 lbs. per square inch, as employed in the "Blake," the "Blenheim," and in several other vessels ordered prior to the date of the Act; and this pressure is now general in the Naval service for boilers of the water-tank type. In the water-tube boilers of the "Speedy" a boiler-pressure of 210 lbs. per square inch is employed.

An analysis of the weights of machinery and boilers shows that in the eight battleships bracketed A the machinery as a whole is lighter per horse-power than in the six battleships of the

"Admiral" Class built prior to the Naval Defence Act; and this increase in horse-power per ton is slightly greater when comparing the boiler-weights alone. The auxiliary machinery is considerably more powerful in the battleships last constructed than in the vessels of the "Admiral" Class, and is therefore heavier; consequently the saving in weight, arising from the employment of triple-expansion engines and a higher steam-pressure, is even greater than the figures appear to show. In addition to this saving in weight, there is considerable economy in coal-consumption in the later vessels as compared with the earlier type which had compound engines.

Comparing the "Barfleur" and "Centurion" with the earlier vessels, it will be observed that the saving in weight is less pronounced; this arises particularly from the nature of the service required of these vessels, which are intended for employment on distant stations, where the duration of steaming will be greater, and the facilities for repairs less.

In comparison with the weights of that of the "Nile" and of the "Trafalgar," the machinery of the battleships built under the Naval Defence Act is seen to be heavier. Some of this difference is explained by the heavier auxiliary machinery fitted in the latter vessels, but it must be mainly attributed to the increased weights of the boilers provided, to secure greater subdivision of the boiler-power, increased facilities for access and repair, and greater durability.

Comparing the 1st Class Cruisers built under the Naval Defence Act with the seven previously referred to, tried in 1887-88, it will be observed that an increase in power for tonnage is shown at the natural-draught powers, which is not maintained when the forced-draught powers are compared. This arises chiefly from the altered ratio which exists between the natural-draught and forced-draught powers in the two instances. The object aimed at in the design of the 1st Class Cruisers built under the Naval Defence Act, was to maintain a high continuous steaming-power, less regard being paid to the possible performances for short periods under forced draught.

A comparison of the weights of the 2nd Class Cruisers (Table C) built under the Naval Defence Act with the five 3rd Class Crusiers bracketed H, Table D, which are the type from which these vessels were developed, exhibits the same general features as the 1st Class Cruisers, though somewhat more marked, the horse-power at forced draught per ton of machinery as well as of boilers being considerably less in the later vessels than in the

earlier. This arises from the causes already mentioned in regard to the 1st Class Cruisers. It is not proposed to carry this comparison further, as what has been mentioned will serve to show the general principles kept in view in determining the weights of machinery of these later vessels.

The machinery of all the battleships built under the Naval Defence Act is arranged in a similar manner, viz., in six separate water-tight compartments, the twin engines being abreast, and the boilers being stoked athwartships. This is illustrated in Figs. 1 and 2, Plate 1. In all the cruisers, the engines are arranged on a similar plan, but the boilers are in two compartments, stoked in the fore-and-aft direction as illustrated in Figs. 5 to 8, Plate 2. It is, of course, well understood that in the design of the machinery for war-ships, special attention has to be paid to requirements arising from the necessity of its protection from damage in action. This generally limits the stroke that can be employed.

As regards the details of the machinery of the Naval Defence Act vessels, space only permits of brief reference to them. The barrels of the cylinders in all except the Torpedo Gunboats, are jacketed and fitted generally with forged-steel liners in the high-pressure cylinders, and either forged-steel or hard close-grained cast-iron liners in the intermediate and low-pressure cylinders. The engine-standards, in all except the Torpedo Gunboats, consist of one cast-steel or iron back column, and two forged-steel front columns for each cylinder. There are occasional deviations from this practice, as will be observed by reference to Plate 3, which illustrates the standards fitted in several of the Battleships and 1st Class Cruisers, where it is seen that the back and front columns of the "Royal Arthur" are of cast-steel of I section, four to each cylinder, whilst those of the "Gibraltar" and "Royal Oak" are of the forged-steel pillar type with bracing. Table F, column 3, gives the weights of these, including the guide-faces. Although there is nothing in the Table to indicate any saving in weight by employing forged-steel rather than cast-steel for the columns, it is interesting as showing the variation in the weights of these parts, and where a saving in weight might occasionally be effected. The main bearing-frames are generally of cast-steel, and are in most cases united by distance-pieces between consecutive frames. The weights of these are given in column 4, Table F. The pistons are of the steel conical type, having generally in the larger vessels wrought-steel junk-rings, and for the most part wide single packing-rings of

either phosphor-bronze or cast-iron held out by tempered steel springs. In the Torpedo Gunboats, Ramsbottom rings of Perkins metal are generally fitted. The crank-shafts and propeller-shafting are hollow and of forged-steel. The condenser-cases are of rolled- or cast-brass. In all, except the Torpedo Gunboats, separate auxiliary condensers are fitted for taking the auxiliary machinery exhaust. For providing fresh water for "make-up" purposes, reserve fresh-water tanks are fitted, in addition to evaporators and distilling-plant.

The valve-gear in all the seventy vessels consists of the ordinary link motion, working in most cases piston slide-valves in the high-pressure, either piston or flat slide-valves for the intermediate pressure, and usually flat slide-valves for the low-pressure engines. The air-pumps are in all cases worked off the main engines, but separate circulating-engines and pumps of the centrifugal type are fitted for the condensers. For the purpose of controlling the boilers more readily, especially under forced draught, separate uptakes are fitted to each combustion-chamber, with hinged dampers workable from the stokehold floor in each uptake.

For the various auxiliary engines fitted in these vessels, open engines have been generally fitted, instead of the closed type formerly used for the same purposes, also a lower speed of revolution has been adopted. Extra weight has, as already mentioned, been incurred on this account, but it is more than compensated by the greater durability of the machinery. With regard to the boilers of these later vessels, it will be observed that those of the single-ended rather than of the double-ended type have been adopted, giving increased plate heating-surfaces, due to subdividing the combustion-chamber, which has the further effect of subdividing the tube-plate area. It is considered that these modifications, though increasing the weight of the boilers, ensure stronger and better steaming boilers of a kind more suitable to the varied requirements of Naval service. Representations from the service afloat have been strongly in favour of this change.

As regards the question of leaky boiler-tubes, its great importance may make a few remarks excusable. Experience has shown that this defect primarily arises from overheating, due either to forced-combustion or to the presence of oily or other deposits on the surfaces exposed to heat; and that this may be mitigated (1) by interposing plate heating-surface to absorb the heat before the flames impinge on the tube-plate and the tube-ends; (2) by the employment of a tube-ferrule so constructed as to prevent the

flame from impinging on the tube-ends and tube-plates, and also to prevent conduction of heat to those parts by means of the air-space between them and the protecting ferrule; (3) by reducing to a minimum the oil employed for internal lubrication, and by the employment of filters or other processes for its extraction. The employment of all these means has reduced the leaky-tube question to one of insignificant character compared with that which it at one time assumed, so that one of the evils consequent on the use of forced draught has been to a large extent successfully combated. In the smaller vessels a less objectionable difficulty has arisen; viz., the gradual closing up of the ferrules at the tube-ends by scoriæ. This appears to depend on the description of coal used, and considerable variation in its amount has been observed. In the return-tube boilers which are fitted in most vessels no trouble arises from this cause, since the tubes are of fairly large diameter. In the locomotive-boiler, however, where the tubes are small, some trouble has been experienced; but experiments are being made with the view of minimising it. A different type of tube-ferrule, more costly than that mentioned, has also been tried satisfactorily in two boilers of the "Medusa," and will be fitted in one of the new battleships.

As already mentioned, water-tube boilers for vessels other than torpedo-boats have been introduced in the "Speedy," one of the Torpedo Gunboats built under the Naval Defence Act. Table E gives the particulars of the performance of this vessel, and the corresponding figures for vessels of the same class will enable a comparison to be instituted. There is seen to be a material increase in the horse-power per ton of machinery and boilers. As regards the working capabilities of this type of boiler, immunity from leaky tube-ends, the readiness with which steam can be raised, and the absence of all special precautions in their stoking, are points in their favour; on the other hand, the small quantity of water in them and the rapid evaporation entail considerable attention in feeding; further, their steam-space is not great, and care has to be exercised to avoid priming. The small diameter of the tubes precludes the use of salt water for feed, and further these boilers exhibit a greater disposition than the water-tank boilers to prime if any cause gives rise to it.

Although not strictly within the range of this Paper, possibly a few words on what is now being done in respect of other boilers of the water-tube type may be of interest. In the "Sharpshooter" (Table E), the boilers of the locomotive type have been removed and replaced by eight water-tube boilers of the Belleville type. It

cannot be said that any increase in horse-power per ton has accrued on this account, but an advantage as regards ability to continuously maintain a high power is shown, arising more particularly from the fact that there are no tube-ends to choke up as in the other type of boiler, and that the whole of the fire-side of the heating-surfaces is readily cleaned when under way. Particulars of the performances of the "Sharpshooter" fitted with Belleville boilers are given in Table E. It is seen that an increase in weight is involved by their installation above that of the boilers at first fitted, but these latter never generated satisfactorily the required power even on trials when new. A more just comparison might be instituted between these figures and those of the later vessels of the class in which the boilers have been increased in size and modified in other ways, in order to enable them to attain their intended power satisfactorily. Compared in this way, the boiler-weights do not exceed those of the locomotive type. It is to be observed from the air-pressures employed, that little or no forcing was resorted to in obtaining the power recorded. In view of the ability of these boilers to maintain a high rate of steaming for considerable periods, and their tactical and other advantages, it has been decided to fit them in the two 1st Class Cruisers "Powerful" and "Terrible" now in course of construction.

An extended use of the water-tube type of boiler is also being made in the Torpedo-boat Destroyers built and under construction. The Table below gives a few particulars of what has been accomplished with these boilers. These figures exhibit the great capability of the boilers to produce steam, but the question of their durability is one that can only be decided after longer experience.

Ship.	Description of Boiler.	I.HP.	Grate-Area.	Heating-Surface.	Weight of Boiler, Mountings, Furnace Fittings, Brickwork and Water to Working Level.	I.HP. per Ton.
			Sq. Feet.	Sq. Feet.	Tons.	
Speedy	Thornycroft	4,704	205	17,700	87·45	53·7
Daring	"	4,300	189	8,892	48·5	88·6
Ferret	Normand .	4,500	154	8,112	50·7	88·7
Hornet	Yarrow . .	3,884	172·8	8,216	44·8	86·7

An experiment has been made in another of the vessels built

under the Naval Defence Act, viz., the "Gossamer," in which the Martin system of induced draught has been fitted to the two forward boilers, the two after boilers retaining their forced-draught fittings, thus enabling a comparison to be made between the two systems. The trials have been numerous and prolonged, and experience at sea has also been obtained during the manœuvres of 1893 and 1894. A brief summary of the most important conclusions arrived at may enable an idea to be formed of the merits of the system. The draught can be accelerated equally by either system, but a fan of considerably larger dimensions is required for the induced draught, and this occupies a disadvantageous position by being placed in the uptake. As regards absence of leaky tube-ends, no superiority can be claimed for induced draught. The formation of scoriæ at the tube-ends occurs apparently to the same extent with both systems. With induced draught, the fitting of a separate fan in the uptake of each boiler places the boilers under better control for cleaning fires, &c. The open stokehold, consequent upon induced draught, enables much freer communication to be kept up with the other machinery spaces. The temperature of the stokeholds is lower, and the stokers work generally in greater comfort; as a consequence, the stoking is better, and this, combined with the maintenance of more perfect control over the fires, helps to reduce the coal-consumption, which the trials show to be lower. This system of draught is being fitted to one of the new 1st Class Battleships now under construction, and to another vessel of the gun-boat class.

Several of the vessels forming the subject of this Paper have been sufficiently long in commission to have made passages at powers approaching their natural draught; and these indicate that the vessels are capable of maintaining, without any special effort, and with their own complement of stokers, a high percentage of their natural-draught powers. A few of these trials may be cited: The "Royal Sovereign," on a passage from Plymouth to Gibraltar, maintained 8,180 I.HP. for seventy-two hours, the coal consumed being 1·84 lb. per I.HP. per hour. The "Royal Arthur," on a passage from Callao to Coquimbo, maintained 8,821 I.HP. for seventy-two hours with a coal-consumption of 1·85 lb. per I.HP. per hour. The "Sans Pareil," on a passage from Malta to Volo, developed 7,051 I.HP. for fifty hours, with a coal-consumption of 2·23 lbs. per I.HP. per hour. The "Sirius," on a passage, maintained 4,555 I.HP. for sixty-four hours, with a coal-consumption of 2·03 lbs. per I.HP. per hour. The "Pallas," on a passage, developed 3,620 I.HP. for seventy-three hours.

The quarterly passage-trials of twenty-four hours' duration made by these vessels furnish further indications of their ability to repeat their trial performances with natural draught. On these occasions the full natural-draught power is maintained for four hours, and not less than three-fifths of the natural draught for the remaining twenty hours.

The Paper is accompanied by six tracings, from which Plates 1, 2 and 3 have been prepared.

[APPENDIX.

APPEN

TABLE A.—

Ship.	I.HP. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights.		Surfaces.	
					Machinery Complete.	Boilers.	Grate.	Total Heating.
		Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
Benbow[1] . .	8,662	..	10,853	1·3	1,274	717·2	798	20,500
Howe[1] . . .	7,730	..	11,725	2·4	1,151	608·4	756	20,726
Rodney[1] . .	8,259	..	11,158	1·4	1,159	636·5	756	20,726
Camperdown[1] .	8,605	..	11,739	2·4	1,276	695·5	826	20,500
Collingwood[1] .	8,100	..	9,570	1·1	1,244	736·1	810	20,776
Anson[1] . . .	8,305	0·2	12,585	1·9	1,149	612·1	797	20,296
Average .	8,277	..	11,271	1·7	1,209	667·6	790	20,587
Nile[2] . . .	9,106	0·5	12,109	1·7	1,017	537·7	600	19,560
Trafalgar[2] . .	8,520	0·5	12,822	2·1	1,013	501·2	659	18,300
Average .	8,813	0·5	12,465	1·9	1,015	519·4	629	18,930
Hero[3] . . .	4,351	..	6,162	1·0	817	483·9	507	14,377
A { Hood[4] . .	9,539	0·4	11,446	1·0	1,155	583·4	734	20,034
A { Empress of India[4] .	9,508	0·5	11,625	1·0	1,149	581·1	728	20,034
A { Repulse[4] .	9,588	0·4	11,314	0·9	1,149	586·6	718	20,034
A { Royal Sovereign[4] .	9,661	0·4	13,363*	1·6	1,159	597·9	718	20,034
A { Ramillies[4] .	9,443	0·2	11,571	0·3	1,159	587·7	711	20,132
A { Resolution[4]	9,248	0·2	11,402	0·6	1,161	608·1	765	21,178
A { Revenge[4] .	9,220	0·2	11,536	0·4	1,158	607·2	765	21,178
A { Royal Oak[4]	9,235	0·2	11,608	0·9	1,216	610·3	710	20,160
Average .	9,430	0·3	11,500	0·8	1,163	595·3	731	20,348
B { Barfleur[5] .	9,934	..	13,163	1·7	1,302	668·4	774	22,317
B { Centurion[5] .	9,711	0·18	13,214	1·5	1,307	660·6	774	22,317
Average .	9,822	0·09	13,188	1·6	1,304	664·5	774	22,317

* Omitted from average.

VESSELS BUILT BEFORE THE NAVAL DEFENCE ACT.

[1] Vertical 3-cylinder compound engines with twin-screws running about 100 revolutions per minute at full power. Stroke, 3 feet 9 inches; piston-speed, 750 feet per minute ("Collingwood," 95 revolutions per minute; 3 feet 6 inches stroke; piston-speed, 665 feet per minute). Boilers of the single-ended, return-tube type, twelve in number, with three furnaces in each; load on safety-valves, 90 lbs. per square inch ("Anson" has eight four-furnace boilers carrying 100 lbs. of steam). Boilers placed in four compartments, arranged back to back against a middle-line bulkhead.

[2] Vertical three-cylinder, triple-expansion engines, with twin-screws running at 95 revolutions per minute at full power. Stroke, 4 feet 3 inches; piston-speed, 807 feet per minute. Fitted with six single-ended return-tube boilers. Boiler-pressure, 135 lbs. per square inch.

[3] Two-cylinder compound-engines; twin-screws; revolutions 109 per minute; stroke, 3 feet; piston-speed, 654 feet per minute; eight single-ended return-tube boilers, with three furnaces in each, loaded to 90 lbs. per square inch.

DIX.

BATTLESHIPS.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete.		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
6·8	8·5	12·0	15·1	10·8	13·6	2·3	1·8	Iron
6·6	11·8	11·0	19·2	10·2	15·5	2·6	1·7	„
7·1	9·6	12·9	17·5	10·9	14·7	2·5	1·8	„
6·7	9·2	12·3	16·8	10·4	14·2	2·3	1·7	„
6·5	7·6	11·0	13·0	10·0	11·8	2·5	2·1	Brass
7·2	10·9	13·5	20·5	10·4	15·7	2·4	1·6	Iron
6·8	9·3	12·4	16·9	10·4	14·2	2·4	1·8	..
8·9	11·9	16·9	22·5	15·1	20·1	2·1	1·6	Steel
8·4	12·6	17·0	25·5	12·9	19·4	2·1	1·4	Iron
8·6	12·2	16·9	24·0	14·0	19·7	2·1	1·5	..
5·3	7·5	8·9	12·7	8·5	12·1	3·3	2·3	Iron
8·2	9·9	16·3	19·6	13·0	15·6	2·1	1·7	Steel
8·2	10·1	16·3	20·0	13·0	15·9	2·1	1·7	„
8·3	9·8	16·3	19·3	13·3	15·75	2·0	1·7	„
8·3	11·5	16·1	22·3	13·4	18·6	2·0	1·5	„
8·1	9·9	16·0	19·7	13·2	16·2	2·1	1·7	„
8·0	9·8	15·2	18·7	12·0	14·9	2·2	1·8	„
8·0	9·9	15·1	19·0	12·0	15·0	2·2	1·8	„
7·6	9·5	15·1	19·0	13·0	16·3	2·1	1·7	„
8·1	10·0	15·8	19·7	12·9	16·0	2·1	1·7	..
7·6	10·1	14·8	19·7	12·8	17·0	2·2	1·7	Steel
7·4	10·1	14·7	20·0	12·5	17·0	2·2	1·7	„
7·5	10·1	14·7	19·8	12·6	17·0	2·2	1·7	..

VESSELS BUILT UNDER THE NAVAL DEFENCE ACT.

[4] Vertical three-cylinder triple-expansion twin-screw engines, designed to run at 108 revolutions per minute at full power 13,000 I.HP. Stroke, 4 feet 3 inches; piston-speed, 918 feet per minute. The valve-gear and propellers (except in "Royal Sovereign") are arranged to work at a maximum power of 11,000 I.HP. in order to obtain more economical results at ordinary rates of working. Boilers of the single-ended return-tube type, eight in number, in four compartments arranged back to back against a middle-line division. Each boiler has four furnaces with two, three, or four combustion-chambers. Load on safety-valves, 155 lbs. per square inch.

[5] Engines generally similar to battleships above. Revolutions at full power (13,000 I.HP.), 105 per minute; stroke, 4 feet; piston-speed, 840 feet per minute. Boilers similar to above, four furnaces, with two combustion-chambers in each. Load on safety-valves, 155 lbs. per square inch.

TABLE B.—

Ship.		I.HP. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights.		Surfaces.	
						Machinery Complete.	Boilers.	Grate.	Total Heating.
			Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
	Australia [1] . .	5,810	Nil	8,876	1·7	780	413·2	513	15,191
	Orlando [1] . .	5,628	..	8,739	1·0	795	430·2	548	15,795
	Undaunted [1] .	5,682	..	8,670	1·8	792	425·6	548	15,795
	Narcissus [1] . .	5,353	..	8,589	2·0	770	434·8	535	15,524
	Galatea [1] . .	5,871	..	9,220	1·1	786	434·3	495	15,191
	Immortalité [1] .	6,090	..	8,738	2·0	772	440·0	492	15,190
	Aurora [1] . .	5,706	..	9,013	1·2	818	457·5	471	15,832
	Average .	5,734	..	8,835	1·5	787	433·6	514	15,502
	Blake [2] . . .	14,525	0·4	..	..	1,559	787·2	871	27,192
	Blenheim [2] . .	14,924	0·2	21,411	2·0	1,543	754·0	1,135	31,073
	Average .	14,724	0·3	21,411	2·0	1,551	770·6	1,003	29,132
C	Edgar [3] . .	10,172	0·3	12,550	0·7	1,135	639·8	849	24,879
C	Hawke [3] . .	10,761	0 3	12,521	0·4	1,144	628·5	812	24,879
C	Endymion [3] .	10,662	0·1	..	..	1,129	654·2	847	25,173
C	Gibraltar [3] .	10,445	0·1	..	..	1,178	606·9	746	24,754
C	St. George [3] .	10,585	0·1	..	..	1,155	670·7	847	25,173
D	Royal Arthur [3]	10,086	0·4	..	..	1,186	663·1	731	24,828
D	Crescent [3] .	10,378	..	..	..	1,188	661·1	860	24,784
D	Grafton [3]. .	10,956	0·4	13,483	1·1	1,164	644·7	875	24,880
D	Theseus [3] .	10,608	0·4	..	..	1,170	650·4	751	24,828
	Average .	10,517	0·2	12,851	0·7	1,161	646·6	812	24,908
	Vulcan [4] . . .	8,167	0·4	12,062	1·8	988	495·5	564	TORPEDO 15,861

VESSELS BUILT BEFORE THE NAVAL DEFENCE ACT.

[1] Horizontal twin-screw triple-expansion engines running 110 and 115 revolutions per minute at full power; stroke, 3 feet 6 inches and 3 feet 8 inches; piston-speed, 770 and 806 feet per minute; fitted with four double-ended boilers, having three furnaces at each end, with either one or three combustion-chambers; steam-pressure, 130 lbs. per square inch, except "Aurora" and "Galatea" 135 lbs., and "Australia" 137 lbs.

[2] Twin-screw triple-expansion engines, two complete sets to each screw shaft, running at 105 revolutions at full speed; stroke, 4 feet; piston-speed, 840 feet per minute; fitted with six double-ended boilers, four furnaces each end leading into one common combustion-chamber in "Blake;" in "Blenheim," two furnaces from the same end unite in one combustion-chamber. Have also one single-ended boiler for auxiliary purposes. Steam-pressure, 155 lbs. per square inch.

1st Class Cruisers.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete.		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
7·4	11·3	14·0	21·4	11·3	17·3	2·6	1·7	Steel.
7·0	10·9	13·0	20·3	10·2	15·7	2·8	1·8	"
7·1	10·9	13·3	20·4	10·3	15·8	2·7	1·8	"
6·9	11·1	12·3	19·7	10·3	16·0	2·9	1·8	Steel, Stay-tubes, Iron.
7·4	11·7	13·5	21·2	11·9	18·6	2·5	1·6	Iron.
7·8	11·3	13·8	19·8	12·3	17·7	2·5	1·7	Steel, Stay-tubes, Iron.
6·9	11·0	12·4	19·7	12·1	19·1	2·7	1·7	Steel.
7·3	11·2	13·2	20·7	11·2	17·2	2·7	1·7	
9·3	..	18·4	..	16·6	..	1·8	..	Steel.
9·6	13·8	19·7	28·3	13·1	18·8	2·0	1·4	"
9·4	13·8	19·0	28·3	14·8	18·8	1·9	1·4	
8·9	11·0	15·8	19·6	12·0	14·7	2·4	1·9	Steel.
9·4	10·9	17·1	19·9	13·2	15·5	2·3	1·9	"
9·4	..	16·3	..	12·5	..	2·3	..	"
8·8	..	17·2	..	13·9	..	2·3	..	"
9·1	..	15·7	..	12·5	..	2·3	..	"
8·4	..	15·2	..	13·7	..	2·4	..	"
8·7	..	15·7	..	12·2	..	2·3	..	"
9·4	11·5	17·0	20·9	12·5	15·4	2·2	1·8	"
9·0	..	16·3	..	14·0	..	2·3	..	"
9·0	11·1	16·2	20·1	12·9	15·2	2·3	1·9	
Depôt Ship.								
8·2	12·2	16·4	24·3	14·4	21·3	1·9	1·3	Steel

Vessels built under the Naval Defence Act.

[3] Vertical three-cylinder triple-expansion engines, twin-screws, engines designed to run at 100 revolutions per minute at full power. Stroke, 4 feet 3 inches; piston-speed, 850 feet per minute. The valve-gear and propellers, except in "Edgar," "Hawke," and "Grafton" are arranged to work at a maximum power of 10,000 I.HP., in order to obtain more economical results at ordinary rates of working. Vessels bracketed C have four double-ended and one single-ended boiler; those bracketed D eight single-ended four-furnace return-tube boilers; steam-pressure, 155 lbs. per square inch.

Vessel built before the Naval Defence Act.

[4] Twin-screw triple-expansion engines, running at 100 revolutions per minute at full power. Stroke, 4 feet 3 inches; piston-speed, 850 feet per minute; fitted with four double-ended return-tube boilers, and one single-ended boiler for auxiliary purposes; load on safety-valves, 155 lbs. per square inch.

Note.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear and all fittings in boiler-rooms; also water in boilers at working-level.

TABLE C.—2ND

	Ship.	I.HP. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights. Machinery Complete.	Weights. Boilers.	Surfaces. Grate.	Surfaces. Total Heating.
			Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
	Mersey[1]	4,515	Nil	6,628	2·0	552	307·9	399	11,711
	Severn[1]	4,603	"	6,335	2·0	552	306·6	399	11,711
	Thames[1]	4,162	"	5,886	1·4	563	311·4	377	11,444
	Forth[1]	3,590	"	5,756	1·9	568	320·2	380	11,393
	Average	4,217	Nil	6,151	1·8	559	311·0	388	11,565
	Andromache[2]	7,234	0·5	9,044	1·3	714	435·5	560	15,389
	Apollo[2]	7,488	0·3	9,226	0·8	715	432·5	560	15,389
	Indefatigable[2]	7,349	0·4	9,047	0·9	735	422·2	588	15,725
	Intrepid[2]	7,522	0·4	9,489	1·2	739	420·9	588	15,725
	Iphigenia[2]	7,251	0·2	9,337	0·8	736	418·0	546	15,725
	Latona[2]	7,261	0·4	9,455	1·3	728	433·6	584	15,512
	Melampus[2]	7,684	0·4	9,135	1·2	713	431·7	588	15,512
	Naiad[2]	7,547	0·4	9,261	1·2	703	425·2	584	15,512
E	Pique[2]	7,515	0·2	9,258	1·0	751	422·8	574	15,704
	Rainbow[2]	7,879	0·3	9,741	0·7	751	422·8	574	15,704
	Retribution[2]	7,645	0·2	9,367	0·6	751	422·8	574	15,704
	Sappho[2]	7,301	0·3	9,618	0·7	727	420·7	593	15,754
	Scylla[2]	7,614	0·2	9,280	0·8	727	421·0	593	15,754
	Sirius[2]	7,491	0·2	9,281	0·8	742	428·0	602	15,918
	Spartan[2]	7,832	0·3	9,254	0·9	742	428·0	581	15,918
	Sybille[2]	7,598	0·1	9,524	0·5	726	425·7	604	16,039
	Terpsichore[2]	7,133	0·2	8,825	0·9	718	402·3	573	15,470
	Thetis[2]	7,034	0·5	9,496	0·7	718	402·3	553	15,470
	Tribune[2]	7,523	0·1	9,101	0·5	718	402·3	553	15,470
	Æolus[2]	7,504	0·1	9,315	0·7	732	417·0	555	15,947
	Brilliant[2]	7,522	0·1	9,180	1·1	732	439·0	556	15,947
	Bonaventure[2]	7,423	0·4	9,365	0·8	797	469·4	553	15,600
	Cambrian[2]	7,164	0·4	9,259	1·0	776	455·0	567	15,600
	Charybdis[2]	7,109	0·5	9,136	1·6	797	488·3	574	15,304
	Flora[2]	7,187	0·4	9,008	1·3	766	458·4	580	15,788
	Astræa[2]	7,603	0·4	9,151	1·4	813	466·9	593	15,287
	Fox[2]	7,034	0·3	9,063	1·3	788	460·0	600	15,655
	Forte[2]	7,427	0·4	9,382	1·1	*800	445·2	584	15,600
	Hermione[2]	7,393	0·4	9,264	0·9	795	481·4	573	15,440
	Average	7,423	0·3	9,271	1·0	748	434·4	575	15,641

* Approx.

VESSELS BUILT BEFORE THE NAVAL DEFENCE ACT.

[1] Horizontal twin-screw compound two-cylinder engines, running about 120 revolutions per minute at full power. Stroke, 3 ft. 3 in.; piston-speed, 780 ft. per minute; fitted with six boilers of the circular direct-tube type, placed in two compartments; boiler steam-pressure, 110 lbs. per square inch.

VESSELS BUILT UNDER THE NAVAL DEFENCE ACT.

[2] Vertical three-cylinder triple-expansion engines, twin-screws, designed to work at 140 revolutions per minute at full power of 9,000 I.HP. Stroke, 3 feet 3 inches;

CLASS CRUISERS.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete.		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
8·1	12·0	14·6	21·5	11·3	16·6	2·5	1·7	Iron.
8·3	11·4	15·0	20·7	11·5	15·8	2·5	1·8	,,
7·3	10·4	13·3	18·9	11·0	15·6	2·7	1·9	Steel.
6·3	10·1	11·2	18·0	9·4	15·1	3·1	1·9	Iron.
7·5	11·0	13·5	19·7	10·8	15·8	2·7	1·8	
10·1	12·6	16·6	20·7	12·9	16·1	2·1	1·7	Steel.
10·4	12·9	17·3	21·3	13·3	16·4	2·0	1·6	,,
9·9	12·3	17·3	21·4	12·5	15·3	2·1	1·7	,,
10·1	12·8	17·8	22·5	12·8	16·1	2·0	1·6	,,
9·8	12·6	17·3	22·3	13·2	17·1	2·1	1·6	,,
9·9	13·0	16·7	21·8	12·4	16·1	2·1	1·6	,,
10·7	12·8	17·8	21·1	13·0	15·5	2·0	1·7	,,
10·7	13·1	17·7	21·7	12·9	15·8	2·0	1·6	,,
10·0	12·3	17·7	21·8	13·0	16·1	2·0	1·7	,,
10·4	12·9	18·6	23·0	13·7	16·9	2·0	1·6	,,
10·1	12·4	18·0	22·1	13·3	16·3	2·0	1·6	,,
10·0	13·2	17·3	22·8	12·3	16·2	2·1	1·6	,,
10·4	12·7	18·0	22·0	12·8	15·6	2·0	1·7	,,
10·0	12·5	17·5	21·7	12·4	15·4	2·1	1·7	,,
10·6	12·5	18·3	21·6	13·4	15·9	2·0	1·7	,,
10·4	13·1	17·8	22·3	12·5	15·7	2·1	1·6	,,
9·9	12·2	17·7	21·9	12·4	15·4	2·1	1·7	,,
9·8	13·2	17·4	23·6	12·7	17·1	2·1	1·6	,,
10·4	12·6	18·7	22·6	13·6	16·4	2·0	1·7	,,
10·2	12·7	18·0	22·3	13·5	16·7	2·1	1·7	,,
10·2	12·5	17·1	20·9	13·5	16·5	2·1	1·7	,,
9·3	11·7	15·8	19·5	13·4	16·9	2·1	1·6	,,
9·2	11·9	15·7	20·3	12·6	16·3	2·1	1·6	,,
8·9	11·5	14·5	13·7	12·4	15·9	2·1	1·6	,,
9·4	11·7	15·6	19·6	12·4	15·5	2·1	1·7	,,
9·3	11·2	16·2	21·7	12·8	15·4	2·0	1·6	,,
8·9	10·5	15·3	19·7	11·7	15·1	2·2	1·7	,,
9·2	11·7	16·7	21·1	12·7	16·1	2·1	1·7	,,
9·0	11·6	15·3	19·2	12·9	16·1	2·0	1·6	,,
9·92	12·4	17·0	21·3	12·9	16·1	2·1	1·7	

piston-speed, 910 feet per minute. In the vessels bracketed E, and "Æolus" and "Brilliant," there are three double-ended and two single-ended boilers, and in the others eight single-ended boilers, of the return-tube cylindrical three-furnace type, with separate combustion-chambers. They are arranged in two compartments, with stokeholds athwartships; load on safety-valves, 155 lbs. per square inch.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler-rooms; also water in boilers at working-level.

TABLE D.—

Ship.	I.HP. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights.		Surfaces.	
					Machinery Complete.	Boilers.	Grate.	Total Heating.
		Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
Scout[1] . . .	2,162	Nil	3,370	1·5	291	174·1	207	6,362
Fearless[1] . .	2,241	,,	3,360	2·0	302	185·8	217	6,439
Average .	2,201	,,	3,365	1·7	296	179·9	213	6,400
Archer[2] . .	2,220	Nil	3,850	1·0	354	206·8	209	6,836
Brisk[2] . . .	2,614	,,	3,816	0·9	354	206·2	209	6,836
Cossack[2] . .	2,335	,,	3,700	1·0	354	208·1	228	6,836
Mohawk[2] . .	2,577	,,	3,398	0·9	352	202·1	228	6,836
Porpoise[2] . .	2,476	,,	3,944	1·0	353	206·2	234	6,836
Tartar[2]. . .	2,554	,,	3,824	0·9	355	204·9	228	6,836
Average .	2,462	,,	3,754	0·9	353	205·7	222	6,836
Racoon[3]. . .	2,647	Nil	4,613	1·5	395	226·6	244	7,878
H { Medea[4] . .	6,027	0·5	9,185	2·2	624	373·5	468	12,628
Medusa[4] .	6,144	..	9,435	1·9	614	363·8	525	12,628
Marathon[5] .	6,530	0·4	8,786	2·3	624	360·2	535	13,616
Magicienne[5]	5,408	0·6	9,280	2·2	627	365·0	535	13,616
Melpomene[5]	6,215	0·4	9,653	1·7	649	369·0	570	13,830
Average .	6,065	0·5	9,268	2·0	627	366·3	526	13,264

VESSELS BUILT BEFORE THE NAVAL DEFENCE ACT.

[1] Horizontal twin-screw two-cylinder compound engines, running at 150 revolutions per minute at full power. Stroke, 2 feet 6 inches; piston-speed, 750 feet per minute; four boilers of circular direct-tube type, arranged in two compartments; safety-valves loaded to 120 lbs. per square inch.

[2] Horizontal twin-screw engines, compound type, running at 150 revolutions per minute at full power. Stroke, 2 feet 9 inches; piston-speed, 825 feet per minute; fitted with four boilers of the circular direct-tube type; boiler-pressure, 130 lbs. per square inch.

[3] Horizontal triple-expansion, twin-screw engines, running at 150 revolutions per minute at full power. Stroke, 2 feet 9 inches; piston-speed, 825 feet per minute; four boilers, circular direct-tube type; boiler-pressure, 140 lbs. per square inch.

3RD CLASS CRUISERS.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
7·4	11·6	12·4	19·3	10·4	16·2	2·9	1·9	Iron.
7·4	11·1	12·1	18·1	10·3	15·4	2·8	1·9	"
7·4	11·3	12·2	18·7	10·3	15·8	2·8	1·9	
6·2	10·8	10·7	18·6	10·6	18·4	3·0	1·7	Iron.
7·3	10·7	12·6	18·5	12·5	18·2	2·6	1·7	"
6·6	10·4	11·2	17·7	10·2	16·2	2·9	1·8	"
7·3	9·6	12·7	16·8	11·3	14·8	2·6	2·0	"
7·0	11·1	12·0	19·0	10·5	16·8	2·7	1·7	"
7·1	10·7	12·4	18·6	11·2	16·7	2·6	1·7	"
6·9	10·6	12·0	18·3	11·1	16·9	2·7	1·8	
6·7	11·6	11·7	20·4	10·8	18·9	2·9	1·7	Steel.
9·6	14·7	16·1	24·6	12·8	19·6	2·0	1·3	Iron.
10·0	15·3	16·9	26·0	11·7	17·9	2·0	1·3	"
10·4	14·0	18·1	24·4	12·2	16·4	2·0	1·5	Steel.
8·6	14·7	14·8	25·4	10·1	17·3	2·5	1·4	"
7·5	14·8	16·9	26·1	10·9	16·9	2·2	1·4	Iron.
9·2	14·7	16·5	25·3	11·5	17·6	2·2	1·4	

4 Vertical twin-screw triple-expansion engines, running at 140 revolutions per minute at full power. Stroke, 3 feet 3 inches; piston-speed, 910 feet per minute; four double-ended boilers; six furnaces, with common combustion-chambers; boiler-pressure, 155 lbs. per square inch.

5 Horizontal twin-screw triple-expansion engines, running at 140 revolutions per minute at full speed. Stroke, 3 feet; piston-speed, 840 feet per minute; four double-ended six-furnace boilers, with three combustion-chambers to each boiler; boiler-pressure, 155 lbs. per square inch.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler-rooms; also water in boilers at working-level.

TABLE D.—

Ship.	I.HP. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights.		Surfaces.	
					Machinery Complete.	Boilers.	Grate.	Total Heating.
		Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
Barrosa [1] . .	2,133	0·4	3,111	1·4	248	151·3	201	4,529
Barracouta [1] .	1,920	0·9	..	..	247	148·3	195	4,529
Blanche [1] . .	1,832	0 6	2,849	1·4	245	142·1	188	4,650
Blonde [1] . .	1,918	0·5	2,762	1·7	245	142·3	188	4,650
Average .	1,951	0·6	2,907	1·5	246	146·0	193	4,589
Katoomba [2]. .	4,538	0·5	..	..	497	288·8	377	10,150
Mildura [2] . .	4,543	0·9	..	..	505	289·0	319	10,150
Wallaroo [2] . .	4,574	0·5	..	..	505	289·0	376	10,150
Tauranga [2]. .	4,651	0·6	..	..	541	281·5	378	9,621
Ringarooma [2] .	4,771	0·4	..	..	529	281·0	378	9,621
Average . .	4,615	0·7	..	..	515	285·8	365	9,938
Barham [3] . .	3,618	1·1	4,561	2·1	273	138·0	244	7,088
Bellona [3] . .	3,566	1·2	..	..	275	141·3	244	7,088
Average .	3,592	1·1	4,561	2·1	274	139·6	244	7,088
Pallas [4]. . .	5,066	0·1	7,333	1·5	516	297·7	425	11,109
Pearl [4] . . .	5,372	0·3	7,227	1·5	543	318·4	400	11,105
Philomel [4] . .	4,923	0·3	7,735	1·2	539	320·9	416	11,105
Phœbe [4] . .	4,705	0·2	7,582	1·6	559	317·4	401	10,782
Average .	5,016	0·2	7,469	1·4	539	313·6	410	11,025

VESSELS BUILT BEFORE THE NAVAL DEFENCE ACT.

[1] Vertical twin-screw triple-expansion engines, running at 200 revolutions per minute at full power. Stroke, 2 feet; piston-speed, 800 feet per minute; two double-ended boilers, with common combustion-chambers; boiler-pressure, 155 lbs. per square inch.

[2] Vertical twin-screw triple-expansion engines, running at 160 revolutions per minute at full power. Stroke, 2 feet 9 inches; piston-speed, 880 feet per minute; fitted with four 2-furnace double-ended boilers, having common combustion-chambers. boiler-pressure, 155 lbs. per square inch.

[3] Vertical twin-screw triple-expansion engines, designed to run at 220 revolutions per minute at full power. Stroke, 2 feet 3 inches; piston-speed, 990 feet per minute; fitted with six locomotive-boilers, wet-bottomed fire-boxes; boiler-pressure, 155 lbs. per square inch.

3RD CLASS CRUISERS—*continued.*

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete.		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
8·6	12·5	14·1	20·6	10·9	15·4	2·1	1·4	Steel.
7·8	..	13·0	..	9·8	..	2·3	..	"
7·4	11·6	12·8	20·0	9·7	15·1	2·5	1·6	"
7·8	11·2	13·5	19·4	10·1	14·7	2·4	1·6	"
7·9	11·8	13·3	20·0	10·1	15·1	2·3	1·5	
9·1	..	15·7	..	12·0	..	2·2	..	Steel.
9·0	..	15·7	..	14·2	..	2·2	..	"
9·0	..	15·8	..	12·1	..	2·2	..	"
8·6	..	16·5	..	12·3	..	2·0	..	"
9·0	..	17·0	..	12·6	..	2·0	..	"
8·9	..	16·1	..	12·6	..	2·1		
13·2	16·7	26·2	33·0	14·8	18·7	1·9	1·5	Steel.
13·0	..	25·2	..	14·6	..	1·9	..	"
13·1	16·7	25·7	33·0	14·7	18·7	1·9	1·5	
9·8	14·2	17·0	24·7	11·9	17·2	2·1	1·5	Steel.
9·9	13·3	16·9	22·7	13·4	18·0	2·0	1·5	"
9·1	14·3	15·3	24·1	11·8	18·5	2·2	1·4	"
8·4	13·5	14·9	23·9	11·7	18·9	2·2	1·4	"
9·3	13·8	16·0	23·8	12·2	18·2	2·1	1·47	

VESSELS BUILT UNDER THE NAVAL DEFENCE ACT.

[4] Vertical three-cylinder triple-expansion engines, twin-screws, designed to run at 160 revolutions per minute, full speed. Stroke, 2 feet 9 inches; piston-speed, 880 feet per minute; fitted with four double-ended cylindrical return-tube boilers, two furnaces at each end, and a separate combustion-chamber to each furnace; boiler-pressure, 155 lbs. per square inch.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler-rooms; also water in boilers at working-level.

TABLE E.—TORPEDO

Ship.	I.H.P. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights.		Surfaces.	
					Machinery Complete.	Boilers.	Grate.	Total Heating.
		Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
Rattlesnake [1] .	..	..	2,740	2·8	133	85·2	126	4,639
Grasshopper [1] .	..	..	2,368	2·8	118	72·4	120	4,396
Sandfly [1] . .	..	..	3,014	2·8	115	72·4	119	4,334
Spider [1] . .	..	..	2,664	2·5	115	72·0	119	4,334
Average .	..	..	2,696	2·6	120	75·5	121	4,426
Sharpshooter [2] .	2,836	0·8	..	..	167	94·3	190	5,330
Spanker [2] . .	2,524	1·0	..	..	163	98·0	182	5,330
Boomerang [2] .	2,612	0·6	3,509	2·0	173	98·0	190	5,330
Karakatta [2] .	2,598	0·5	3,840	1·7	171	95·6	190	5,330
Salamander [2] .	2,825	0·9	..	..	175	109·2	153	5,319
Seagull [2] . .	2,792	1·8	..	2·3	176	109·4	144	5,319
Sheldrake [2] .	2,659	0·9	..	..	..	109·0	153	5,319
Assaye [2] . .	2,774	1·1	..	..	174	100·0	153	5,980
Plassy [2]. . .	2,895	0·9	..	..	176	97·6	153	5,980
Skipjack [2] . .	2,282	0·6	3,931	3·4	170	102·5	192	5,469
Speedwell [2] .	2,601	0·5	3,588	2·8	168	102·0	191	5,469
Average .	2,672	0·9	3,717	2·4	171	101·4	172	5,470
Sharpshooter [3] .	2,620	Nil	3,238	0·1	197	124·3	269	7,695

VESSELS BUILT BEFORE THE NAVAL DEFENCE ACT.

[1] Vertical twin-screw triple-expansion engines. Revolutions per minute at full power—"Rattlesnake," 310; "Grasshopper," "Sandfly," and "Spider," 300. Stroke, 1 foot 6 inches; piston-speed—"Rattlesnake," 930 feet per minute; "Grasshopper," "Sandfly," and "Spider," 900 feet per minute; four locomotive-boilers, wet-bottomed fire-boxes, single combustion-chamber, water-legs fitted in fire-box of "Rattlesnake." Fire-box shell of "Grasshopper" circular instead of the usual locomotive

GUNBOATS.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete.		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
..	..	..	..	..	..	..	..	Steel
..	20·0	..	32·8	..	19·7	..	1·85	"
..	26·2	..	41·8	..	25·3	..	1·43	"
..	23·1	..	37·0	..	22·3	..	1·62	"
..	23·1	..	37·2	..	22·4	..	1·63	
17·0	..	30·1	..	15·5	..	1·8	..	"
15·4	..	25·7	..	13·8	..	2·1	..	"
15·1	20·2	26·6	35·8	13·7	18·4	2·0	1·5	"
15·1	22·4	27·3	40·4	13·6	20·2	2·0	1·3	"
16·1	..	25·9	..	18·4	..	1·8	..	"
15·8	..	25·6	..	19·3	..	1·9	..	"
15·1	..	24·4	..	17·3	..	1·9	..	"
15·9	..	27·7	..	18·1	..	2·1	..	"
16·4	..	29·8	..	18·9	..	2·0	..	"
13·4	23·1	22·3	38·5	11·8	20·4	2·3	1·3	"
15·4	20·7	25·5	35·1	13·6	18·7	2·0	1·5	"
15·6	21·6	26·4	37·4	15·5	19·4	2·0	1·4	
13·3	16·4	21·1	26·1	9·8	12·0	2·9	2·3	

form. Steam-pressures—"Rattlesnake," 140 lbs.; "Sandfly," and "Spider," 145 lbs.; "Grasshopper," 150 lbs. per square inch.

[2] Similar to above, but larger engines, running at about 250 revolutions, at 3,500 I.HP. Stroke, 1 foot 9 inches; piston-speed, 875 feet per minute.

[3] After being fitted with Belleville boilers.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler-rooms; also water in boilers at working-level.

TABLE E—

	Ship.	I.HP. on Trial, Natural Draught.	Air-Pressure.	I.HP. on Trial, Forced Draught.	Air Pressure.	Weights. Machinery Complete.	Weights. Boilers.	Surfaces. Grate.	Surfaces. Total Heating.
			Inch.		Inches.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
F	Alarm[4]	2,593	0·8	3,886	2·4	220	130·1	156	6,241
F	Circe[4]	2,621	0·9	3,508	1·9	219	129·5	156	6,241
F	Gleaner[4]	2,606	0·9	3,632	2·7	174	109·8	155	5,578
F	Gossamer[4]	2,634	0·9	3,654	2·7	167	103·4	183	5,654
F	Hebe[4]	2,702	0·7	3,566	2·0	216	129·1	163	6,241
F	Leda[4]	2,696	0·8	3,597	2·2	217	128·8	156	6,241
F	Antelope[4]	2,653	0·5	3,597	1·3	211	128·6	179	6,228
F	Jaseur[4]	2,546	..	3,711	2·7	207	121·0	182	6,220
F	Jason[4]	2,676	0·9	3,552	2·1	208	122·5	180	6,220
F	Niger[4]	2,710	0·8	3,785	2·2	209	122·0	182	6,220
F	Onyx[4]	2,526	0·8	3,548	2·1	210	125·1	169	6,197
F	Renard[4]	2,609	0·8	3,962	2·5	210	123·6	169	6,197
G	Dryad[4]	2,696	0·9	3,709	2·2	233	129·5	183	6,301
G	Halcyon[4]	2,590	1·0	3,546	2·0	231	129·0	182	6,204
G	Harrier[4]	2,709	0·9	3,592	1·8	233	129·0	182	6,204
G	Hazard[4]	2,621	0·8	3,734	2·1	233	134·7	172	7,086
G	Hussar[4]	2,548	0·8	3,525	1·7	*232	129·0	182	6,204
	Average	2,631	0·8	3,652	2·1	212	124·4	173	6,204
	Speedy[5]	3,046	0·5	4,703	1·7	212	107·2	204	17,700

* Approx.

VESSELS BUILT UNDER THE NAVAL DEFENCE ACT.

[4] Vertical triple-expansion twin-screw engines, designed to run at 250 revolutions per minute at full power. Stroke, 1 foot 9 inches; piston-speed, 875 feet per minute; boilers of the locomotive wet-bottom fire-box type, four in number, in two compartments; all except "Gossamer" (which has a single fire-box) are fitted with two fire-boxes and tube-nests.

continued.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.
Machinery Complete.		Boilers.						
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	
						Sq. Feet.	Sq. Feet.	
11·8	17·6	19·9	29·8	16·6	24·9	2·4	1·6	Steel.
11·9	16·0	20·3	27·1	16·8	22·4	2·3	1·7	„
14·9	20·8	23·9	33·3	16·7	23·4	2·1	1·5	„
15·7	21·8	25·5	35·4	14·3	19·9	2·1	1·5	„
12·5	16·5	20·9	27·6	16·5	21·8	2·3	1·7	„
12·4	16·5	21·0	28·1	17·2	23·0	2·3	1·7	„
12·5	17·0	20·7	28·1	14·8	20·1	2·3	1·7	„
12·3	17·9	21·0	30·6	14·0	20·3	2·4	1·7	„
12·8	17·0	21·9	29·1	14·8	19·7	2·3	1·7	„
12·9	18·1	22·2	31·0	14·3	20·7	2·2	1·6	„
12·0	16·9	20·2	28·3	14·9	20·9	2·4	1·7	„
12·4	18·8	21·2	32·2	15·4	22·2	2·3	1·5	„
11·5	15·9	20·9	28·7	14·7	20·2	2·3	1·7	„
11·2	15·3	20·0	27·4	14·2	19·4	2·3	1·7	„
11·6	15·4	20·9	27·8	14·9	19·7	2·3	1·7	„
11·2	16·0	19·5	27·8	15·2	21·7	2·7	1·9	„
11·0	15·2	19·7	27·3	14·0	19·4	2·4	1·7	„
12·4	17·2	21·1	29·4	15·2	22·1	2·36	1·7	
14·3	22·1	28·4	43·9	14·9	23·0	5·8	3·7	Steel

" Gossamer " and " Gleaner " are fitted with smaller tubes than the later vessels of the class. Load on safety-valves, 155 lbs. per square inch.

[5] Engines of same type as above, but designed for 4,500 I.HP. at 250 revolutions per minute. Fitted with eight water-tube boilers of Thornycroft type.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler-rooms; also water in boilers at working-level.

TABLE F.—COMPARISON OF WEIGHTS OF FRAMING.

Ship.	Bedplates.				Standards and Guides.				Total.				Remarks.
	Tns.	cwt.	qrs.	lbs.	Tns.	cwt.	qrs.	lbs.	Tns.	cwt.	qrs.	lbs.	
Royal Oak .	32	8	3	12	37	6	2	16	69	15	2	0	Forged-steel front and back columns.
Ramillies .	37	19	0	16	40	2	2	12	78	1	3	0	Cast-steel back columns. Forged-steel front columns.
Crescent . .	36	1	0	24	46	0	2	10	82	1	3	6	Cast-iron back columns. Forged-steel front columns.
Gibraltar .	40	16	1	16	26	7	3	1	67	4	0	17	Forged-steel back and front columns.
Royal Arthur	20	5	0	20	27	10	1	17	47	15	2	9	Cast-steel columns, back and front.
Endymion .	32	0	1	12	22	2	1	22	54	2	3	6	Cast-steel back columns. Forged-steel front columns.

NOTE.—The engines of all these vessels have cylinders of the same dimensions.

[DISCUSSION.

Discussion.

Sir ROBERT RAWLINSON, President, proposed that a hearty vote of thanks be given to the Author for his interesting Paper. He hoped that Englishmen would be gratified and satisfied with the statements it contained, and he should not be at all surprised to learn that foreigners would be exceedingly pleased to have the opportunity of studying it. England must come into rivalry with the rest of the world, and he did not know that secrecy in any department had ever served any State. Most certainly Englishmen could not be accused of practising secrecy in the important matter that the Author had brought forward. Sir Robert Rawlinson.

Mr. A. J. DURSTON thanked the members for the kind manner in which they had received his Paper. He pointed out that in Table E it was stated that the I.HP. of 43·9 per ton of boilers was obtained in the "Speedy" on the forced-draught trial. A foot-note stated that the "boilers" included all boiler-room weights, whereas in a special Table, referred to near the end of the Paper itself, it was stated that 53·7 I.HP. was obtained per ton of boiler with certain figures. The difference was caused by the different weights taken into account in the two separate statements set forth in the foot-notes, and the headings of the columns respectively. His object in preparing the Paper had been to place before the Institution, in a form convenient for reference, the results of trials in most of their naval ships. There had also been included the weights assigned to machinery and boilers, and the ratio of heating- to grate-surface adopted in various types of machinery during recent years. These were submitted as official records of what had been done, for the information and criticism of the members of the Institution and others, from which of course it was hoped considerable benefit would result. Mr. Durston.

Sir E. J. REED said all he could hope to do, in immediate response to a call by the President, was to make a few general remarks with the view of indicating the lines on which some parts of the discussion at any rate might proceed. He need hardly say that he had joined most cordially in the vote of thanks which the meeting had been invited to give to the Author for this Paper. The Navy of this country, as the Paper well showed, was the source of enormous effort, and of vast experience in ship-building and marine engineering; and he had sometimes regarded it as Sir E. J. Reed.

Sir E. J. Reed. a great misfortune that the heads of the technical departments of the Admiralty were so greatly pressed with public work that they could hardly do either themselves or their professional brethren justice, because of lack of opportunity of placing their work fully and clearly before the profession. He had been at the Admiralty at a time when the work of the department must have been light indeed compared with the labours of to-day; and when he thought, as he sometimes did, of the mass of responsible work which his friends Dr. White and the Author had had to do during the last few years, at the same time remembering the amount of administrative work demanding their daily attention in the management of the British Navy, he wondered that they could ever find sufficient time and freedom of mind to come forward on such occasions as the present. The Paper was an exceedingly valuable one. The Institution would have been grateful to the Author if he had merely made it a record of facts; and must be much more grateful for the inferences and reflections with which the Paper concluded. There were some things in the practice of to-day that he did not fully understand, and he would be gratified if the discussion on the Paper, which he could not help thinking would be very full and extensive if time could be allowed for it, should range over questions which were of a public and important character; and should not take a turn, which such discussions frequently took, into advocacy and descriptions of the inventions and schemes of individuals. One thing he would like to hear discussed was the relation between the diameters of the high- and low-pressure cylinders, in regard to which there was in the Navy a very great diversity of practice. The Author had given excellent reasons and explanations for some of the diversities, but he confessed that whether he regarded the statements of the dimensions and the proportions of the machinery of Her Majesty's ships, or whether he dealt with outside practice, he was sometimes puzzled to account for the great differences prevailing between the ratios of the high- to the low-pressure cylinders in modern triple-expansion engines. In some cases the ratio was stated by the Author as 1 to 2·37, and in many cases it was more than double that amount. He did not know whether his figures were quite right, but he had quoted them to illustrate the great range of practice that existed. It appeared, roughly speaking, that with a given boiler, producing a given quantity of steam at a given pressure, there must be a best practice in respect of the apportionment of the dimensions of the cylinders in which it was expended.

Sir E. J. Reed.

He had had occasion lately to consider the matter in connection with actual engines for ships, and would therefore like to hear that question discussed, and to know why it was better in some cases to give the low-pressure cylinder double the ratio that it bore in other engines to the high-pressure cylinder. He wished to refer to one remarkable point of progress. He remembered well what a great step it was thought to be when the late Mr. John Penn, in the machinery of the "Bellerophon," undertook to have a piston-speed of 600 feet per minute. Something like that or a little more had first been used, but now piston-speeds of over 900 feet per minute were employed. Reference had been made by the Author to the fact that in designing vertical steam-engines for Her Majesty's Navy the height was limited because of the desirability of avoiding exposure of the machine. Apart from that consideration, that fairly raised the question whether it was much better or not, if it could be done, to obtain that high speed of piston with a long stroke, and a moderate speed of revolution; or whether there was any great disadvantage in getting it, as it was obtained in some of the cases quoted, with a very short stroke and a very high speed of revolution. He noticed that some of the horizontal engines mentioned in the Paper had a piston-speed of something like 840 feet per minute. He was willing to avow his ignorance as to the advantage or otherwise obtained by the high piston-speed with a greater or smaller length of stroke. He knew some of the obvious advantages of the long stroke, and some of the obvious advantages of the shorter stroke, but he would like to hear the question discussed from a more philosophic point of view, so as to set up a standard of the best, from which necessity might cause a departure one time this way and another time that way, aiming not only at attaining good results but also other objects which ought to be pursued. He wished to make a passing remark in memory of two deceased engineers; one, the late Sir Joseph Whitworth, who, before hollow shafts for marine engines existed, frequently conversed with him as to the desirability of producing them. He would also like to refer to the late Dr. Kirk and to the important part he played, as many members would know, in the introduction of triple-expansion engines, in devising proper standards for supporting the cylinders of engines of that type. In so doing, he rendered service of the most important character, and, in fact, in these particulars might be said to have led the way to the improvements which had been adopted. One or two observations in the Paper which he did not quite understand appeared to invite a little further discussion—

Sir E. J. Reed. for instance, as to what had regulated in all respects the question of weight of machinery and boilers in relation to the power to be developed. Attention had been directed by the Author more than once to the fact that certain sacrifices had been made on account of the necessity in certain vessels of keeping station for a long time abroad, and of avoiding the necessity for repairs. That was, no doubt, a consideration to have in the mind; but he would like to know, more particularly if the information could be obtained in the course of the discussion, how far that had operated in varying the designs of the machinery and boilers, because here again there must be for engines something like a typical standard of weight for a given I.HP. He would like to know how that weight was increased or diminished, and particularly how it happened that in war-ships intended to keep foreign stations, there was any greater necessity for simplification or durability than might arise in line-of-battle ships when engaged in a European war, not exactly in home waters, but in the Mediterranean or other places. The question was one of very great importance, and was deserving of further consideration. The remark had reference to the cases of the "Barfleur" and "Centurion," in which there was less saving of weight in the machinery than in many of the other vessels. He was not suggesting that the course taken had not been a perfectly wise and proper one; but it was one that would bear a little further explanation and justification than had been afforded. The Paper was one of the greatest possible value to the Institution. He had frequently experienced considerable difficulty in obtaining information of an extensive character of the very kind embodied in the Paper and contained in the Tables; and the Author had done himself great honour in the explanations he had given, and the careful and proper spirit in which he had discussed them. For instance, in regard to the case of the water-tube boilers, a subject which had excited a great deal of attention and discussion, the Author had in a few statements apparently given the cream of existing knowledge. He did not know whether that would prove to be so. Other speakers might doubt or question some of the points; but, so far as he knew anything about the question, the inference which the Author had drawn from recent experience in connection with these boilers seemed to be perfectly sound and good. He hoped that before the debate closed the present position in regard to the question of forced draught would be defined a little more exactly. It had been explained by the Author that one of the principal troubles arising from its intro-

duction had been overcome. If that were so, and no remaining troubles of importance were mentioned, he would like to know what there was to prevent ships that were being built to develop an enormous forced draught, when necessity arose, from doing it under trial or at any other time. There might be reasons not known to him, but it was a matter of very great importance, because in considering the capabilities of the Navy, and considering the practice of the Admiralty as being worthy of more or less imitation, he would like to know—at least he continually found himself wishing to know—exactly the state of the question with regard to forced draught. He asked the question the more readily as it contained no kind of reflection upon the Admiralty or upon the Author. In fact, he thought the Paper showed in a very remarkable manner the great professional courage which had been displayed by the Admiralty in connection with marine engines during the tenure of office of Dr. White and the Author at the Admiralty. He took as a single instance the application of the Belleville boiler to such ships as the "Powerful" and "Terror," which formed a striking example; but there were a great many others. They had known perfectly well that had they adhered to a single type of boiler or of engine, and pursued in a too conservative spirit one form of practice, they would have been exposed to a thousand criticisms, not only by the inventors, who were ready to criticise anybody and everybody, but by the general public, who took an interest in their affairs. He did not think anyone could read the Paper, still less study it at their leisure, without coming to the conclusion that the Admiralty had shown very great courage. It was not a light thing, dealing with such an immense service as the British Navy, to introduce great novelties and run the risk of hostile criticism that followed very often upon such introductions. These risks had been run in a very proper and becoming spirit, and he was delighted to have the opportunity of returning his thanks with those of the rest of the members to the Author, not only for the Paper placed before them, but for the enterprising spirit which he had imported into the management of the marine engineering department of the Navy. Sir E. J. Reed.

Mr. A. F. YARROW observed that the Paper dealt with a period which would always be remembered as one in which a great advance had been made in marine engineering; and comparing the results obtained with what had been possible only a few years ago, it would be admitted that the improvements in marine practice which had taken place were as striking as during any period since the Institution was established. At the present time a horse-power Mr. Yarrow.

Mr. Yarrow. was obtained with a weight and within limits of space which but a few years ago would have been considered impracticable. Looking carefully into the causes which had led to this advance, with a view to studying in what direction future advances might be made, it would be seen that they must be attributed firstly to the much greater speed of piston now made practicable, by the reduction of the weights of the moving parts and by the proper balancing of all reciprocating parts. As an example he would here mention that the piston-speed in some engines was now as high as 1,200 feet per minute, indicating as much as 4,000 HP. The advance which had been made was, secondly, due to the use of materials of greater strength; thirdly, to the adoption of an increased working-pressure; and, fourthly, to the recent development of the water-tube boiler to replace that of the ordinary marine type. It was, therefore, not unreasonable to assume that if, in the future, the directions pointed out in the past were followed, a still further advance would probably be secured. The introduction of manganese-bronze for many of the parts had led to great reduction in weight when substituted for cast-iron, their relative strengths being in the ratio of about 3½ to 1. One conspicuous advantage of the adoption of this material had been found in the case of screw propellers, for which not only reduced weight was an advantage, but the exceedingly smooth and true surface which was obtained increased the efficiency. In this respect copper alloyed with aluminium seemed to promise an even superior result. No doubt, in the future aluminium might be looked to as enabling a further important reduction of weight to be made; and aluminium alloyed with nickel, made in the United States, had great promise. With the cost of aluminium still further reduced, there was doubtless a wide field open for its application. Pistons, piston-valves and other moving parts were already being made of this material. Regarding steel, a reduction of weight might be obtained by the use of steel of a higher tensile strength than customary in marine work, which, however, did not possess so great an elongation as the softer material now in use. He believed that a reduction in elongation would not result in any injurious consequences, if not carried too far, with steel as at present obtainable, although formerly it was doubtless very necessary. He mentioned these points as showing the direction in which a reduction of weight and possible advance was at the present time obtainable. In regard to water-tube boilers, it was a remarkable fact that many designs of that type of boiler resembled very closely what was done many years ago, and had been recently brought to notice

in the interesting Paper read by Sir Frederick Bramwell at the last meeting of the British Association.[1] At that time, however, engineers had not the excellent materials now available, which might perhaps account for this class of boiler not having found favour until recently. It would be admitted that the action of the Admiralty, at the instigation of the Author, in taking the lead in introducing water-tube boilers into the Navy, although no doubt many failures might be experienced at first, would be regarded in the future as a wise policy, giving as it did official sanction to what represented an important advance. Mr. Yarrow.

Mr. J. I. THORNYCROFT considered the Paper to be of great value, because it not only showed what the present practice of the Navy was, but also gave an insight into the working of that practice; it showed the advantages which had been derived by particular arrangements, and also illustrated the defects which had shown themselves in the machinery at present in use. In the machinery of war-ships that part of them was being considered which was intended to make them quick, and to give them the mobility which was so necessary, and the importance of which was being more and more felt. He believed the success which had attended the Japanese Navy in the far east had been to some extent due to the superior speed of its ships, and the question of what could be done to increase the speed of ships must be considered most attentively. To obtain high speed in war-ships, not only must the engines and the boilers be light, but no unnecessary fuel must be carried. The result of the examination he had made into the Paper had led him to the conclusion that in seeking to make the machinery light they had perhaps sacrificed too much in the way of economy of fuel. A point the importance of which had been called to mind some time ago by Mr. Normand, of Havre, was the influence of the reduction of weight in one part of the vessel on all the others. It had been said that a little weight here or there did not matter; but any weight put into one part of a ship required an addition in all other parts; it meant carrying more fuel and making a larger ship. The larger the ship the larger were the engines required to drive it, and another small addition to the fuel had to be considered. It had been stated by Mr. Normand that any addition to one part meant more than four times that addition in the complete ship. Mr. Thornycroft had come to the conclusion that no definite rule could be laid down for this ratio; it depended partly on the rate at which the resistance Mr. Thornycroft.

[1] Report, British Association for the Advancement of Science, Oxford, 1894.

Mr. Thornycroft. of the ship was augmented, because by increasing its dimensions the ship was made more economical to drive. In that case an addition to the weight would perhaps not make so great an addition to the ratio by which the weight of any part had to be multiplied in considering the entire addition to the weight of the ship. On the other hand, with a ship which actually became less economical to drive as its size was increased (which under certain conditions was also possible), a different result was obtained. The reduction of weight had been sought in the engines, but he thought, in examining what had been done in the Royal Navy, it would be found that that had been worked down to a very fine point, so that much more could not be done in that direction. Again, in studying the importance of economy of fuel, the radius of action should be taken into consideration. If the radius of action of a ship was intended to be long, then the fuel became a very large element, and economy in consumption was most important. In that case it was advantageous to use a ratio of cylinders in the engines much larger than the ratio of cylinders in a vessel which was only intended to work to a small radius of action. In regard to the subject of high-speed launches, he had read a Paper some years ago before the Institution showing that the number of revolutions of the engine was a most important factor in the weight of the engine; in fact, it might be said that a good engine would almost develop power in proportion to its rate of turning; but of course many parts of the engine, such as the condensers and other parts, were not changed by the rate of turning. The surface depended upon the amount of steam used and was not changed by the rate of turning. But the source of gain in increasing the rate of turning was very limited, and was largely governed by the requirements of the propellers. If it were convenient to use a large number of small propellers, in that case the more rapidly moving engines might be used; but at present he believed that not more than three screws had been used, except in the case of the "Livadia," which had not been very successful. Two screws seemed to be the usual number employed, and in the engines of large ships the rate of turning seemed to be limited to something like 100 per minute, or rather more, whereas in small ships 200 or 300 revolutions had been obtained. Comparing the practice in the merchant marine with that in the Navy, it being important to get the highest economical results in the merchant marine, a larger ratio between the high- and low-pressure cylinders had of course been used, and the boiler-surfaces were also larger. In the Navy the great step

that had been made appeared to be in the change of the boilers; in the engines there did not appear much to be done. An examination of the Tables in the Paper showed what had been done with tank-boilers. He would divide tank-boilers into two kinds—the locomotive and the cylindrical. He did not think cylindrical boiler was quite a good description. It was a short cylinder; it had such large disk ends that a drum would, he thought, be a more appropriate name. The amount of surface to be stayed in the so-called cylindrical boiler was very extensive; the internal combustion-chambers retained much of the form of tanks put in the original form of boilers where the boiler was fitted to the ship so as to take up the room, being put sometimes against the outside of the ship and stoked in the middle; the corner was cut off and it fitted into the ship, the pressure not being a consideration. But as the pressures increased in the use of the marine boiler it became necessary to make it circular. Still, there were those large flat ends left which were all stayed, and the internal chambers also required to be stayed. One point to which he would call attention later was the great weight of the present form of boiler, which was due, as he had pointed out, to the fact that in the ordinary marine boiler there was a strong envelope, which contained not only the water and steam which must necessarily be within the boiler, but also contained the fire and the gases which need not necessarily be within it. That was one cause of the great weight of the marine-boiler. The present form of boiler now appeared to be worked to its limit. It would be seen from an examination of the Tables in the Appendix that the amount of heating-surface per HP. had been decreased pretty uniformly to about 1·7 square foot. There were exceptional cases in which it was less than that, but the result generally was that the Table was incomplete, and there were numerous examples, especially in the vessels of the "Sharpshooter" type, where the particulars for forced draught were absent. The Paper gave ample evidence that the boiler had been worked to its limit. The tubes began to leak, and when the boiler was made long, to save the weight of some of the disk ends, trouble was given with the leaky shell; and it was therefore found best to cut the boiler in two and protect it from those strains which took place owing to the cold bottom of the boiler. Perhaps it was not quite cold, but the bottom of the boiler did not rise to the temperature of the other parts. It was, perhaps, worthy of remark that if an ordinary Galloway boiler was fitted up without a flue running under it, it would soon leak. It was necessary to take some fire under the boiler to keep the bottom warm. The practice in the Mr. Thornycroft.

Mr. Thornycroft. Royal Navy had been to cut down the weights as far as possible, and he had come to the conclusion that more heating-surface was desirable. He thought it evident that some new departure was necessary, and he was glad to see that that new departure had been made. Experiments had been made with the Belleville boiler of the "Sharpshooter." That was a boiler in which the fire was external to the strong envelope. It was considerably lighter than the drum-boiler, and a little lighter than the locomotive boiler; but it had quite as large tubes. The surfaces, however, he thought, were not sufficiently divided. Although the step made was in the right direction, it was not sufficient; it was only taking partial advantage of what could be done. It was perhaps true that when the experiment had been made, and when the "Powerful" and the "Terrible" had been arranged to be fitted with the same boilers, the available knowledge did not justify any further step. He thought, however, that he could show that the Belleville boiler was too heavy. That led him to a consideration of the comparative weights of different boilers. Very valuable information could be obtained on the subject from the Paper, but it was not all comparable on the same terms, because in the Table given in the Paper itself it would be found that boilers were compared without the weight of some of the fittings, the chimneys, and other parts, whereas the ash-hoists and all the engine-room fittings connected with the boiler were included in the Appendix Tables. A little correction was required with regard to the figures given for the "Speedy," the "Daring," the "Ferret," and the "Hornet." In the figures for the "Speedy" the total surface of the tubes was given. It was unfortunate that the total surface of the tubes had to be paid for, but it was not all available as heating-surface. In fact, part of the tube-surface in the boilers of the "Speedy" constituted the external surface of the boiler, and it was like considering part of the shell of an ordinary boiler to look upon it as heating-surface. With regard to the "Daring," there was a clerical error in the HP. The HP. of the three hours' trial was 4,409. The weight of the boiler wanted a little correction, he made it 47·7 tons. Taking those figures for the HP. and the weight, he deduced that the boilers in the "Daring" gave 92½ I.HP. per ton of boiler. The "Ferret" was compared on the same terms as the "Daring," and as a comparison was made of the relative values of the boilers, the "Ferret" having feed-heaters, a little correction must be made; because the effect of feed-heaters taking heat from the steam after it had passed two of the cylinders was really to add to the boilers, and the

additional weight of the feed-heaters, he thought, should be added to the boilers. He was sorry to bring down a rival boiler in value, but he thought that it was fairly brought down to 84 I.HP., as compared with 92½ I.HP. It had been thought that results of that kind could be obtained with the drum or the locomotive boiler, but he thought that must be a mistake. In regard to the relative values of different boilers, it was convenient to consider the weights of the surfaces, because the measure of a boiler was the amount of heating-surface it provided for boiling water. Considering the different boilers mentioned in that way, he found that the weight of the drum-boiler with all the fittings amounted to 0·027 ton per square foot, and the other form of tank-boiler, the locomotive boiler, to 0·020. Taking the weight of the boilers in the "Speedy," it was a curious coincidence that their weight per square foot of surface was exactly the same as the difference between the weights of those boilers; in other words, it was only 0·007 ton per square foot. The figure for the "Daring" appeared to be 0·006, but that was neglecting the weight of the funnels and certain other fittings which were included in considering the ships. In the case of the "Sharpshooter," in which the weight of the Belleville boiler was considered, the figure was 0·016 ton. That was less than the locomotive, but more than twice that of the "Speedy," and the weight per foot of surface of the "Speedy's" boilers was about a quarter of the weight per foot of surface of the drum-boiler, taking the mean value as given in the Paper. A Paper that had been read by Sir Frederick Bramwell before the British Association,[1] was a most appropriate one for the present time, and showed that when engineers, some years ago, were put to the very difficult task of making an engine run on a common road, which was far more difficult than on a railway, they had been driven to use a light boiler, and they had taken the right step in highly dividing their heating-surface. Some of them had used water-tube boilers and others had used modifications of other boilers. But amongst boilers that were pressed very hard it was worthy of remark that the boiler that gave the most trouble was a stayed-surface boiler which brought discredit to the other coaches. He believed it was satisfactorily proved by experiments made on tubulous and ordinary boilers that the effect per unit of heating-surface was about the same. That being the case, the conclusion was reached that the weight of boiler to do equal work depended on the weight of its surface, so that the figures he had mentioned

Mr. Thornycroft.

[1] Report, British Association for the Advancement of Science, Oxford, 1894.

Mr. Thornycroft. gave an indication of the weight that must be expected for doing the work required. He would now make a comparison of endurance under forced draught. It had been stated by the Author that boilers of the Thornycroft water-tube type would not work with salt water. He might mention that one of their boats had made a journey across the Atlantic largely with salt water and that no known damage had resulted. The boat had started with fresh water, and had not used any make-up from the distiller, but had taken it all from the sea. In comparing the Thornycroft boilers with those of the drum type under forced draught, a very great contrast had been found. He thought it was a fact that the drum-boiler usually failed sooner or later under forced draught. It failed if much grease got into it, and it would not stand the quick raising of steam. Changes of the rate of working were almost fatal to it, and it suffered from being cooled down. The question of salt water was perhaps a little doubtful, but in regard to the other things there was no comparison between the two boilers. With the boilers of the "Daring," trials had been made for more than six months, and he was glad to be able to say that after very hard work they had not cost a penny for repair. With reference to forced draught, he had come to the conclusion that, as the Author had pointed out, it did not much matter how forced draught was produced, the effect being very much the same. He believed that forced draught was fatal to tank boilers, and that very tall chimneys were sometimes troublesome. In considering boilers for a particular ship it was important not only to know what power they wished to develop but what was to be the radius of action. The radius of action must have an influence in such consideration, and he thought that for long voyages, for great radius of action, ample heating-surface was required, and forced draught would not be wanted. For large ships water-tube boilers might be made to give ample steam with much greater economy than was now obtained and without forced draught. In the case of small vessels with short radii of action and very high speeds, forced draught was most essential. In fact results could be obtained by it which were quite impossible without it. There had now been extended experience with the water-tube boiler with small tubes in the "Geyser," which had been considered by the Author to be liable to prime. In the "Geyser" special precautions had been taken to avoid priming, but he was sorry to say that Captain Neilsen did not wish them described; it might be mentioned, however, that a reservoir was used besides the upper vessel of the boiler, and Captain Neilsen had said that under no circumstances had he

experienced any trouble with priming. Mr. Thornycroft's firm had made propelling machinery for a life-boat in which a water-tube boiler was used, and the results obtained had been most satisfactory. The boat was exceedingly short, and had gone out in very rough seas. The man who had accompanied it described it as standing on end. That, perhaps, was not quite true, but he could quite believe that the boat was in a position which was inconvenient for the boiler; but they had had no trouble with it. The experience with the "Speedy" had been most satisfactory, and the economy of fuel he believed would be found to be greater than in any other ship, without special precautions being made. The cylinders in the "Speedy" were not steam-jacketed, whereas some of the vessels in the Navy had steam-jacketed cylinders, and perhaps a larger ratio of expansion. The "Speedy" had the advantage of a higher pressure than the other vessels. With that exception the "Speedy" was at a disadvantage. With reference to the "Sharpshooter," he believed that tubulous boilers were right, and that the Author was justified in saying that those boilers would stand for a lengthened period without trouble. That would be a great improvement on the rest of the "Sharpshooter" class. A number of boilers had been built having small water-tubes, in which other materials than steel had been used, and in which the circulation had not been, perhaps, as good as it might have been. He thought it was proper for the tubes to deliver above the water-level, as in that way a more steady circulation was obtained. Some of those boilers with tubes of copper or brass had given trouble, and tended to do damage to the cause of the water-tube boiler. In the German Navy that type of boiler had already been not only proposed, but was being now introduced in a ship of 4,800 HP. The boilers were of amply sufficient power for their work, and of very much less weight than would be required in the ordinary way. He considered that for the Navy the drum-boiler had been improved to its utmost limit, and that no further development could be made. The particulars of the boilers required to be considered for each case, and no general rule could be laid down for the ratio of cylinders with a particular boiler as suggested by Sir Edward Reed, but he thought the radius of action of the ship should be considered in reference to that question. Mr. Thornycroft.

Sir Frederick Bramwell.

Sir FREDERICK BRAMWELL, Past-President, asked whether, in the comparisons made by Mr. Thornycroft between different boilers, he had in all instances included water up to the working-level, and also the casings to the water-tube boilers, and the cleading of the so-called tank boiler.

Mr. Thornycroft.

Mr. Thornycroft replied that he had included both particulars.

Mr. Sampson.

Mr. John Sampson thought that it would be interesting to know the reasons which had induced the Admiralty to adopt steel in place of iron for the tubes of boilers in H.M. ships. He had heard many eminent marine engineers express a strong opinion that much of the trouble experienced with leaky tubes could be traced to the employment of steel tubes for boilers in the Navy. Particulars had been given by the Author of sister ships fitted with similar engines and boilers, some with iron and others with steel tubes. It would be of interest to know what difference, if any, had been found in actual practice between iron and steel tubes, especially as regards leakage when steaming at full power, or what consideration had led to the adoption of steel tubes exclusively for war-ships. It had been further stated by the Author that air-pumps were in all cases worked off the main engines. It had occurred to him that much power was wasted in working the large air-pumps attached to marine engines, especially those running at high speeds. It would appear that, provided there were no leaks in a condenser, the work required of an air-pump was very small. He had particulars of trials of the U.S. cruiser "Columbia." The main machinery was fitted with separate vertical direct-acting air-pump engines; and, at full speed, the main engines indicating about 18,000 HP., and making 131 revolutions per minute, the air-pumps were worked at an average of only fifteen double strokes per minute, maintaining a vacuum of 25·6 inches of mercury. The ratio of the volume swept by the air-pump bucket, at the speed mentioned, to that of the low-pressure cylinder was as low as 74·4 to 1. The total HP. of the main air-pump engines was 56·3, or, in other words, about $\frac{1}{320}$ of the total I.HP. of the main engines. That appeared to him to be a step in the right direction, as the air-pumps could be made to work by a very simply arranged direct-acting engine without crank-shafts. They were noiseless; and they worked at such low speeds that there was practically no wear and tear. In the case of a twin-screw ship two would require to be fitted, the pipes being connected, so that in the case of one breaking down the other pump could do the work for both main engines. He was aware that separate air-pumps had been tried; but perhaps the conditions under which they were then working were somewhat different from those which formerly obtained. It might be that a single-acting air-pump, connected by beams and links to the main engine, did not require much power to drive it; but in practice he believed it did; for instance, the engines of the "Columbia" would require

air-pumps, according to the usual naval dimensions, of about 35 inches in diameter and 18 inches stroke; and, supposing the pumps were disconnected from the main engines, steam-cylinders were added to the pump-rods, and those 35-inch pumps and beams were driven at the rate of thirteen double strokes per minute (that was, at the same speed as main engines), the indicator cards taken from those cylinders and compared with the cards from existing engines which only made fifteen strokes per minute, would show that a considerable amount of valuable power had been uselessly expended. With the high speeds now obtaining it was desirable to simplify the main engines as much as possible, and to confine their work to driving the propellers only. With regard to water-tube boilers, he thought the Author was to be admired for the plucky manner in which he had tackled a most difficult question; but he might go even farther. Having procured a boiler capable of carrying steam-pressure of between 300 lbs. and 400 lbs. per square inch with safety, it might be trusted that he would not limit the pressure at the engines to the usual 160 lbs. or 200 lbs. Without high pressure the water-tube boiler would have no reason to exist, but, having adopted it, advantage should be taken of its capabilities by raising the steam-pressure of the engines accordingly. The triple-expansion engine was found in actual practice to give better results than might have been expected from it when considered theoretically. With steam-pressure of over 200 lbs. per square inch the gain theoretically did not appear great, but it was probable that by adopting a four-crank engine, quadruple-expansion, and by balancing moving parts, placing No. 1 crank opposite No. 2, and No. 3 opposite No. 4, and using a steam-pressure of say 250 lbs. per square inch, another important stride might be made in the direction of economy of fuel and reduction of wear and tear. That appeared to be an experiment which could not be better tried than by the Admiralty, material and workmanship having now reached that stage of perfection which warranted the adoption of increased working-pressure in the engines. Mr. Sampson.

Mr. J. P. Hall said he had had something to do with the Naval Defence Act, six sets of machinery for six of the vessels built under that Act, and five of those which preceded them referred to for a comparison, having passed through his hands. He was, therefore, in a position to congratulate the Author not only upon the Paper as a clear statement of what was being done at the Admiralty, but also upon the great success attained by the seventy vessels described. Five and a half years ago the Naval Defence Mr. Hall.

Mr. Hall. Act had been a gigantic undertaking; it was now a marked success, the whole of the work having been marvellously well carried out in every detail. The two points which in his opinion had led partly to that success were, the great allowance of weight for the machinery, about which engineers had formerly complained, and the very ample space which the builders of the engines had had at their disposal. That was clearly put forward in the Tables and by the diagrams. In reference to battle-ships, the allowance for weights was 1,150 tons, which he thought would satisfy all engineers, and the space occupied was extremely liberal. First-class cruisers were even more amply provided for, the weight being about 1,200 tons. From Table C, second-class cruisers, it appeared that the weight varied between 714 and 813 tons. Since the "Sappho" and "Scylla" (727 tons) had been contracted for, the weights had been materially increased. In later vessels the weight allowed was 800 tons, which was practically 10 per cent. more than the weight in those bracketed E in the Table. That had been a step in the right direction. The increase in the weights was due to the subdivision of boilers as pointed out in the Paper, and he made no special objection to the additional weight in this class of vessel, but at the same time he did not despise the double-ended boiler, with three furnaces in each end and one combustion-chamber common to two furnaces, fore and aft, which had in the past served the mercantile marine and also the Admiralty perfectly well. He could assert with confidence that the "Sappho" and "Scylla" could at any time do their work with ease and safety, and, considering the air-pressure now used, he thought the weight allowed (727 tons) was a liberal one. The torpedo gunboats, Table E, formed a class of vessels in which the weights had been materially increased. In the three vessels which his firm had engined, the "Circe," "Alarm," and "Leda," the weights had been 220 to 217 tons, say 218 tons, and in the case of other vessels the weights had been as low as 207 and 208 tons. To reduce the weight of these engines to 207 tons was a step he would not like to take, and he considered that 220 tons was a fair and reasonable weight. The only reduction which he could suggest was on the boilers, which had been made to Lloyd's requirements; for he thought that, with the supervision and care exercised in the manufacture and working of boilers in the Navy, something less might suffice. During the last five and a half years his firm had had to do with all the classes of vessels referred to, and he was pleased to say that the design and construction of the machinery of each individual vessel built under the Naval Defence

Act had been amply well carried out. Indeed, the programme of the Act had been in his opinion a marked success in every way. There was one point on which he did not agree with the Author's conclusions, viz., that in reference to the application of the Martin system of induced draught to the "Gossamer." Referring to leaky tubes, it had been stated by the Author that as regards absence of leaky tube-ends, no superiority could be claimed for induced draught, and that the formation of scoriæ at the tube-ends apparently occurred to the same extent with both systems. For himself he believed in induced draught, for which he thought there was a great future. The "Gossamer," however, might not have been a very good case in which to apply it. He believed that the tubes had been severely punished by forced draught before the introduction of induced draught. With regard to ferrules with induced draught he thought they should not be used, his impression being that with induced draught the tubes would be very much more effective without ferrules, and that this would have been especially so in the case of the "Gossamer," the vessel having small tubes which were further reduced by fitting the ferrules. By reducing the diameter of the tubes, the ferrules prevented the free entrance of the flame, impeded the flow and held the scoriæ, which otherwise would have passed as dust up the chimney. He hoped, therefore, that the Author would postpone coming to any definite conclusions on the subject until he had had the opportunity of trying induced draught upon a new boiler without the ferrules. Engine-builders had hitherto complained that they had not had sufficient latitude given to them by the Admiralty. He remembered that, when the Boiler Committee sat, the enquiry to many had been made whether engineers had a sufficiently free hand. Evidence had now been given that they had a free hand. Battle-ships had been described in the Paper of various classes, including five ships of the same size, the "Gibraltar," "Royal Arthur," "Ramillies," "Crescent," and "Royal Oak," as shown on the diagrams, with cylinders of the same diameter and stroke, but in other respects no two alike. He felt quite sure that engineers would be satisfied with the free hand they now had. The Admiralty also would benefit by it, obtaining, as they would, the experience of various engineers throughout the country. Reference had been made by Sir Edward Reed to what had been done twenty years ago by the late Mr. John Penn, and to a piston-speed of 650 feet per minute having been obtained. Mr. Hall had since ascertained that nearly a quarter of a century ago the "Sultan" had been fitted with trunk engines, with cylinders 127 inches in diameter, and Mr. Hall.

Mr. Hall. a stroke of 4 feet 6 inches, running at 73 revolutions per minute, giving a piston-speed of 657 feet per minute, with an I.HP. of 9,500, the maximum on trial being from 9,500 to 9,600. The fact of nearly 10,000 HP. having been transmitted through one shaft twenty-five years ago deserved to be recorded.

Mr. Gross. Mr. F. Gross had no intention to criticise any portion of the results relating to boilers chronicled in the Paper, but wished to place on record the results of trials of a new system of draught which promised to be of considerable use in the immediate future. The original experimental plant consisted of five single-ended marine boilers, part with plain tubes, part with "Serve" tubes, which could be worked with natural, Martin mechanical suction, or Howden forced draught. The results had shown (1) that suction draught with all air-pressures negative was preferable to the positive pressure of forced draught, because the boiler was heated more uniformly and not so severely locally, the action being that of largely increased natural draught; (2) that, taking all the circumstances into consideration, a cylindrical boiler of the same size and with draught of equal value could not, with plain tubes, be as economical as one with Serve tubes; and (3) that the cooling of the gases after they left the boilers, necessary for the sake of the exhausting fans, could be used for heating correspondingly the bulk of the air required for combustion. The recognition of those facts had led to the combination known as the Ellis-Eaves system, consisting of suction draught, heating the air by the waste gases, and using "Serve" tubes and retarders. The installation on those lines of two boilers of the same dimensions as the earlier experimental plant had proved anticipations of them to be correct, and the number of boilers had gradually been increased to ten. In daily work the average combustion in the boilers was 35 lbs. per square foot of grate 5 feet 8 inches long, and the average maximum power of combustion was 45 lbs. Some boilers could burn as much as 60 lbs. on the same size of grate. At a combustion of 30 lbs. to 35 lbs. per square foot of grate, the evaporation from cold feed with ordinary South Yorkshire coal was 9 lbs. of water actual or 10½ lbs. from and at 212° F., at 45 lbs. per square foot it was 8½ lbs. and 10 lbs. respectively. With best South Wales coal the results were ¾ lb. better in each case. Any kind of coal could be burnt without smoke. With a combustion of 45 lbs. per square foot of grate, the temperature of the gases on reaching the fans did not exceed 450° F., and the air was heated to 300° F. The first two boilers were now three and a-half years old, the next

two were two and a-half years old, and there had been no trouble with fans and fan-engines, furnaces, grates, tube-plates and the tube ends, which were entirely unprotected. The system had been used in two sister ships, named the "Perthshire" and "Buteshire," built by Messrs. Hawthorn, Leslie and Co., Newcastle, of over 10,000 tons displacement, with triple-expansion engines to develop 3,000 I.HP. Each had two single-ended main boilers 15 feet 6 inches in diameter and 12 feet long, with six Purves flues of 3 feet 9 inches inside diameter, with a grate-area of 127 square feet, heating-surface in the boilers 4,770 square feet, and working pressure of 160 lbs. per square inch. At full power each furnace therefore had to develop 500 I.HP. Those boilers, with their water and the draught installation complete, including funnel, weighed 228 tons, and could easily give and maintain the 3,000 I.HP. of the main engines. The usual work was to develop about 2,500 I.HP. with the main engines, and on the return voyage the main boilers had also to supply the steam for extensive refrigerating machinery. On arrival in Australia the boilers were cleaned, and they had then to be continually under steam, whilst collecting the meat at the various ports, bringing it to London and discharging it there, for about 90 days. In port the boilers worked chiefly with natural draught, for which they were perfectly suitable, having Serve tubes of $3\frac{1}{4}$ inches outside diameter, and good funnel height. On the outward voyage the work had equalled therefore 11 I.HP. per ton of boilers, or nearly 20 I.HP. per square foot of grate. On the homeward voyage the evaporation, being equal to at least 2,750 I.HP. of main engines, was nearly 12 I.HP. per ton of boilers and 22 I.HP. per square foot of grate-surface. At the full power of 3,000 I.HP. that was equivalent to over 13 I.HP. per ton, or nearly 24 I.HP. per square foot of grate-surface. Small coal was generally used, and could quite conveniently be burned with that system. The coal-consumption per I.HP., including that for the fan engines, averaged 1·35 lb. for Newcastle small coal, and less than 1·3 lb. for South Wales ordinary bunker coal. At 1·3 lb. the combustion was 30 lbs. per square foot of grate. He could further point to two large new steamers, the "Southwark," built by Messrs. Denny, and the "Kensington," by Messrs. J. and G. Thomson, for the American line, of over 12,000 tons, to develop 7,500 I.HP. with twin-screw quadruple engines, having cylinders $25\frac{1}{2}$ inches, $37\frac{1}{2}$ inches, $52\frac{1}{2}$ inches and 74 inches in diameter and 54 inches stroke. The boilers were similar to those of the Australian steamers, viz., two double-ended, 15 feet 9 inches in diameter Mr. Gross.

Mr. Gross. and 21 feet 8 inches long, and one single-ended, 15 feet 9 inches in diameter and 11 feet 3 inches long, grate-surface 383 square feet, heating-surface 12,500 square feet, four Purves furnaces, of 3 feet 4 inches inside diameter, in each end, and a working pressure of 200 lbs. per square inch. Both these vessels on their voyages west had developed about 7,500 I.HP., or nearly 20 I.HP. per square foot of grate, which, in all cases, was 5 feet 9 inches long. Those performances were not short trial-trip performances, but were repeated results of regular long voyages, practically as certain and safe as if they were natural-draught ships with twice the number of boilers, and they compared favourably per square foot of grate with the forced-draught trial results of the present Admiralty cylindrical boilers and the Belleville boilers, although they were not yet as light per I.HP. In considering the question of weight, it was, however, necessary to bear in mind that the steam in the ships named was produced much more economically. Based on the long series of their comparative trials, an economy of at least 10 per cent. was obtained over the present Admiralty cylindrical boilers with natural draught, and more against forced draught. Reckoning an average of 2,750 I.HP. for a fifty days' voyage, at only 10 per cent. economy, a saving of weight of 158 tons of coal had been effected, and left the weight of boilers and coal together in favour of the "Perthshire," as on the question of weight, the result was the same as if the boiler installation complete weighed, say 70 tons with the ordinary coal consumption per I.HP. That relation would occur in all long-voyage steamers and warships intended to carry large quantities of coal. If the "Perthshire" were fitted with natural draught and four single-ended boilers of the present size, the weight of her installation would be 145 tons greater. If those natural-draught boilers had plain tubes, they would require to burn at least 10 per cent. more fuel to give the same amount of steam. If they had "Serve" tubes, they would burn the same amount for the same evaporation. Consequently the existing installation gave the same economy with 145 tons less weight and half the floor space.

The arrangement was such that the space and weight of the boilers and coal combined could for large ships be kept below that required for cylindrical and water-tubular boilers with coal, and possessed all the advantages of suction-draught, explained by the Author, with the additional advantage of large diameter tubes, ample water and steam spaces, and the immunity from leaky tube-ends, the readiness with which steam could be raised, and the absence of all special precautions in their stoking, which

had been mentioned in favour of the water-tube boiler. In the trial of suction-draught pure and simple, leaky tube-ends had been found by the Author, but Mr. Gross was convinced that if large diameter Serve tubes, say $3\frac{1}{4}$ inches outside diameter, were used, the same immunity from leaky tube-ends and blocking by scoriæ would be obtained. The introduction of the Serve tube, with twice the amount of heat-absorbing surface, enabled the use of the same outside diameter as with ordinary natural draught. In France the Admiralty used the Serve tube entirely in their cylindrical boilers, and the lower rows of the water-tubular boilers. Some 400 locomotives were already running there with Serve tubes $2\frac{5}{8}$ inches in diameter, instead of plain tubes of $1\frac{3}{4}$ inch to $1\frac{7}{8}$ inch diameter. There was no reason for using a smaller diameter Serve tube than $3\frac{1}{4}$ inches, even for a combustion of 54 lbs. to 60 lbs., and an evaporation of 30 to 40 I.HP. per square foot of grate 5 feet 6 inches to 6 feet long, which they can readily give on land. From the absence of trouble with the first boilers on this system, now three and a half years old, which had been subjected intentionally to the roughest treatment, it might be reasonably inferred that for endurance and life they would compare most favourably with others. Mr. Gross.

Mr. A. E. SEATON thought the Paper might be regarded as a monument of the engineering skill and enterprise of the country. The Institution was to be congratulated on such a Paper being read within its walls, since it was fulfilling its proper function of embracing all kinds of engineering, and especially those branches which were of such importance to a maritime country. The Author had done great service by epitomising the results of the ships built under the Naval Defence Act, and the more the figures in the Paper were considered the more instruction would be gleaned from them. He had not had an opportunity of studying the Paper as deeply as he could desire; but the first point that had attracted his attention was the information the Author had conveyed that at a comparatively late period of their construction certain ships had been directed to be worked at something under the forced-draught power for which they had been designed. He thought that was a step eminently in the right direction, and events had proved it to be so. He had always felt strongly the necessity of obtaining moderate economy even from such engines as those of which the Author had to direct the construction. Reference had been made by Mr. Thornycroft to the radius of action of ships, which he had understood was the distance that a ship was capable of travelling at moderate speed Mr. Seaton.

Mr. Seaton. with a certain coal-supply. He did not know that the term was used with reference to performances under forced draught. He thought the Author had made a step in the right direction when he altered the settings of the valves of certain ships so that their I.HP. was somewhat less than was expected under the contract. The wisdom of such a course had been proved by the event, because, in the case of his own ships, the I.HP. of which had been reduced from 12,000 to 10,000, little more than 10,000 HP. had been required to get the speed that was laid down for the ship, under forced draught, with 12,000 HP. In fact, a higher speed was obtained with a considerable economy of fuel. He was sorry that more figures than the Author had quoted had not been given. Perhaps the Author did not attach the same importance to fuel-consumption as those sometimes did who had to pay for the coals. He attached considerable importance to the subject for that reason. Ships built by him had succeeded in running their trials at what might be called moderate forced draught, with a consumption of 1·69 lb. per I.HP. in one ship, and of 1·62 lb. in the other. He did not want to grind axes, but he felt proud of that result, because he thought it was the lowest that had been attained in any ship of that class, and compared favourably with the figures given by the Author. It should be stated that the results had not been obtained by himself or by his staff, but had been furnished by the dockyard officials who superintended the trials. A little mistake had been made by the Author in his summary. The engines which his firm had made had not forged steel columns, but steel castings, and were not like those of the "Royal Arthur," but were from an entirely new design, having some of the characteristics of the other design. It would be noted that the standards and guides weighed only 22½ owt. against 46 cwt. in other ships. The "Royal Oak," which appeared to be the lightest, was actually the heaviest. The point was interesting, and had occurred also in the design of the torpedo-boat destroyers. It had been concluded that the lightest form of engine was that with turned steel columns. On enquiry he had found that a design with back cast columns could be made really lighter than with forged turned columns. The total weight of frames and standards had been stated by the Author as 54 cwt., and at first sight that did not appear to compare favourably with those of the "Royal Arthur," but the ships as well as the engines had been built by his firm, who had to make the seatings as well as the castings. With regard to the question of forced draught, he did not understand how any engineer could be misled by such terms as negative

and positive draught, and he did not see how the action on the tubes would be in any way different, whether the air was blown into a stoke-hole by a blower or came into the stoke-hole because the blower was sucking the contents out of the funnel. His view upon that matter appeared to be corroborated by the Author's opinion. That the induced draught system was a convenient and cheap one he freely admitted, and in 1872, when Sir Edward Reed was designing a very fast ship, Mr. Seaton had schemed a similar device for him, with the object of doing without a funnel. With regard to the air-pump question, Mr. Sampson had expressed a hope that some one other than Messrs. Maudslay would try an independent air-pump. When his firm were entrusted with works under the Naval Defence Act, they had considered the point, and he therefore knew something about the matter and could speak with some confidence. One of his first endeavours had been to work the whole of the pumps by independent engines, but, whereas there was no difficulty with circulating pumps, feed-pumps, and bilge-pumps, the utmost difficulty had prevailed with air-pumps. In the first place he had found that more space was occupied by them than was allowed. The space which had been allowed in the ships had been referred to by Mr. Hall. Mr. Seaton admitted that the Engineer-in-chief had allowed plenty of weight, but the same liberal allowance had not been made in regard to space. He had therefore found it at the outset very desirable to have an independently worked air-pump, but room for it could not be found. But there had been, however, another difficulty, viz., that the pump was almost uncontrollable. The only method he could conceive of controlling it was by the old-fashioned cataract. He need not enter into the scientific aspect of the question, but he would simply state that the air-pump was the most difficult of all to control. He had been informed that the pumps of the United States cruiser "Charleston" had been found to be uncontrollable. He remembered twenty-five years ago having seen a ship fitted with independent air-pumps by Roger of Glasgow. In those days a jet-condenser was used, and there was no uncertainty as to the amount of water obtained at each stroke. He thought the Author had acted very wisely in striking out boldly for the use of the water-tube boiler. His firm had removed the insides of a large number of cylindrical boilers to put in new ones, and they were generally found to be a great deal worse when they were opened up than they appeared to be on cursory examination. The insides of those boilers gave a large amount of trouble. As had been said in a recent letter to

Mr. Seaton.

Mr. Seaton. "Engineering," there were Howden boilers, now twenty years old, which were still in good condition. He could say the same for boilers that he had had the pleasure of making twenty years ago, but not all the Howden boilers, or those made by his own firm twelve years ago, were now in existence. H.M. ships were on totally different service from those in the mercantile marine. All classes of H.M.'s ships were called upon at short notice to perform service. At any time, especially in war-time, it would be impossible to give a war-ship the necessary notice in order that steam might be raised in such time as not to injure a large double-ended cylindrical boiler of 180 lbs. per square inch pressure. The fact had been overlooked by Mr. Howden that twenty years ago boilers were made for a pressure of 60 lbs. per square inch instead of 180 lbs. He agreed with the Author that for H.M.'s ships single-ended boilers were undoubtedly better than double-ended. He also agreed with Mr. Hall that double-ended boilers had been useful in the past, and, with reasonable care, they were serviceable now. They were, however, treacherous if they were not treated properly. On the other hand, the water-tube boiler, whether Belleville, Thornycroft, Yarrow, or Babcock-Wilcox, had the quality of enduring rough usage. In a boiler in his own works, the fires had been lighted and steam had been raised in thirty-five minutes, and in another case in thirty minutes, and no harm had been done. The amount of coal consumed in getting up steam had been very small. The circulation in the boiler had commenced directly the fire began to burn, and the bottom of the boiler was as hot as the top within a few minutes of the fire being lighted. All those points were of the utmost importance in dealing with boilers for ships likely to be called upon to perform service at short notice. He did not suppose that the Belleville boiler had been adopted by the Admiralty without the fullest consideration. It had the merit of very large tubes, and he had been especially struck with one passage in the Paper bearing on that point. He thought that the mistake in both the Yarrow and Thornycroft boilers was the presence of small tubes next the fire. He thought those boilers would be materially improved if one or two rows next the fire were considerably larger than the other tubes and somewhat thicker. It was desirable to reduce the violent action in those tubes, and to prevent them from absorbing the large amount of heat that they were capable of doing, and allowing more to pass to the next lot of tubes. That was a mere matter of detail that could be easily overcome. In the case of such boats as the

torpedo-boat destroyers, one of them might be lying in a little creek, and receive orders to go on service at full speed. There would be no time for nursing the boilers, as it would be necessary to raise steam immediately. The water-tube boilers were capable of that. The locomotive boiler, with all its virtues, which he did not desire to minimize, could not compare with the water-tube boiler in that respect. Upon one set of figures given by the Author he looked with some amount of disappointment, viz., those in reference to I.HP. obtained in the ships per foot of grate. The disappointment was that it was so small considering what Mr. Gross was doing at Sheffield, but it probably arose from a slight misconception of the facts. In H.M. service, as in every other fleet of steamships, the best fuel could not be always procured. The vessels might go to a station where the fuel had been under a burning sun for months, and what engineers called the "nature" of the coal was gone out of it, so that a great deal had to be burned to get the necessary amount of steam. If the coal were good, one half the grate-area might be sufficient. That brought him to the point that, if the grates were not made too large, there was no limit to the air-pressure that might be put on the boilers. What had happened in the past had not been due to any particular pressure, whether ½ inch, or 3 inches, or 6 inches; the question was, what amount of heat had it been tried to pass through the tubes in a minute or in an hour. Whether the heat was obtained with a short grate and intense draught, or a long grate and a dead draught, did not signify. The question was the amount of heat it was attempted to pass in the chamber, and from the chamber through the tubes. In the case of naval boilers the introduction of a ferrule specially adapted for the purpose had overcome the difficulty. It had been very properly stated by Mr. Gross that, in order to secure success with induced draught on their system, there must be a Serve tube, because a Serve tube by its large diameter allowed ample space and ample water in the neighbourhood of the tube-plate. That was a great thing, and it was what the Author did not find in the boilers for which he was not responsible. Mr. Seaton.

Mr. J. P. Symes pointed out that in Table A of the Appendix a class of eight vessels of the "Hood" type had been mentioned, and said he should be glad if the Author would explain the statement that in that particular class there were "boilers of the single-ended return-tube type, eight in number, in four compartments, arranged back to back, against a middle line division; each boiler has four furnaces with two, three or four combustion- Mr. Symes.

Mr. Symes. chambers." Water-tube boilers were coming into use; the other boilers were out of date for the very high pressure now being used. He wished to know why three classes of boilers were placed in one ship. No doubt each of them had its advantages, but it appeared to him remarkable that those three different classes should be placed in one ship. In Table B reference had been made to ships of the "Blake" type, fitted with six double-ended boilers, with four furnaces at each end leading into one combustion chamber. If the same efficiency could be obtained from boilers of these two classes, supposing the external dimensions to be the same, there was great advantage of the latter boiler over the former. There was a saving in the weight of the boiler itself, the saving in the workmanship was very considerable, and there was also a saving in the weight of the water carried.

Dr. Kennedy. Dr. A. B. W. KENNEDY wished, in calling attention to a few omissions in the Paper, to state at the outset, that he could not hold the Author responsible for those omissions, because he had no doubt if the Author could have filled up the blanks to which he was about to refer he would have done so. He might even go farther and say, although he had not had an opportunity of speaking to the Author on the matter—that he was not only sure that he would have been most pleased to give the information, but he strongly suspected that the Author was entirely in accord with him in wishing that he were able to give it. Special stress had been laid by the Author on the ratio of HP. to weight, and he had determined those quantities, or enabled others to judge of them, solely by quoting the total weight of the machinery and boilers and the total HP. obtained under different conditions. He ventured to think that this was incomplete in one or two ways. In the first instance it was obviously incomplete because the weight of the coal carried must be taken into account. A vessel had to carry not only her machinery and boilers, and the water in the boilers, but coal for a certain number of days' run, varying no doubt in different classes of ships. Taking the run approximately as ten days at such powers as were given on the last page of the Paper, it might be roughly said that the total weight of coal did not differ much from the total weight of the boilers, water and machinery. It was therefore a quantity the weight of which was of the very first importance. That opened up a very wide question, and a question with regard to which it was not at all easy to form a correct opinion or make a good comparison between different

results unless not only the weight of the machinery (using the word in the general sense), the speed of the ship and the I.HP., but also the weight of the coal used per hour under given conditions were given. He thought that to obtain a good result they should also know the weight of the water used per hour under given conditions. Without those quantities he thought that the department over which the Author presided was working under very great difficulties indeed, because it was attempting to design, and was indeed actually designing, machinery (against which machinery he had nothing to say) with most imperfect data as to what that machinery would actually do. He could not too strongly emphasize the fact that it was really a matter of necessity to know the amount of coal and the water used per hour for a given HP. and therefore for a given speed, in order that the designers might have a secure basis to work upon. Moreover, those figures should be known separately, otherwise it was impossible for anyone to judge whether a saving could be made on the engines or on the boilers, or on both, or on neither. In 1886 a Paper dealing with marine engine design was read at a meeting of the Institution of Mechanical Engineers,[1] and he then ventured to bring forward the point he was now urging. He had been told at once that the thing was impossible, and that water and coal could not be measured at sea—certainly not water. Indeed a generous offer had been made to put a steamer at his disposal to make any measurement he liked as long as he did not attempt to measure water or to do anything so foolish. Happily he did not accept the offer, but from the discussion at that meeting originated the appointment of a Research Committee of the Institution of Mechanical Engineers, which, whatever else it did, at least showed that it was quite possible under the ordinary conditions of the merchant service to measure coal and water on board ship without interfering with the regular conditions of working. The engines tested certainly did not indicate 13,000 HP., but their HP. was at least measured by thousands, and that was no small matter. He thought that if what might almost be called a scratch company of amateurs could manage to do this under difficult and disadvantageous circumstances, there could be no physical difficulty in the way of doing it in the Navy; at least, if there was, it was time that those difficulties were overcome. He had heard it said that there was always the great difficulty of want of time. He believed he was not putting it too

Dr. Kennedy.

[1] Institution of Mechanical Engineers, Proceedings, 1886, p. 504.

Dr. Kennedy. strongly in saying that this was not a true difficulty, because he did not think a ship of such importance as any of the vessels in question—everything connected with which was of national importance—could be considered finished and ready for service until the particulars he had mentioned were known. Except in the case of war, or some serious matter of that kind, ships should no more go away without the Author and his department knowing the figures connected with its actual economical working, than she should go away without her cylinder-cover, or the blades of her propeller. He was glad to take that opportunity of expressing what he believed was the view of many engineers, that this matter was of really vital importance; indeed, he thought Dr. White would be in great difficulties in his designing, if he had not beside him the results which he could get from experiments made on model vessels, such as he knew were now used to a large extent. Unfortunately, experiments could not be made on models as to the amount of coal which would keep the ship running at a certain speed for ten days; that had to be done on the ships themselves, and it was no doubt much more troublesome and difficult to do. But he ventured to think that until that information was obtained, at whatever trouble, and put into the hands of the Author and his colleagues, they would be as badly off, and would be working under as many difficulties in their enormously important duties, as Dr. White would be if all the scientifically-obtained information which fortunately he was able to get from models were swept away, and he had to work upon data which were as rough in comparison with his own work as the data on which the engineering department had to work, viz., the data which the Author had given so fully in his Paper, and which, from the point of view he was trying to place before the meeting, were after all incomplete.

Prof. Biles. Professor J. H. Biles hoped the Author would state the pounds or tons per I.HP. instead of the I.HP. per ton. He had given in the Table a column of figures with regard to the machinery complete, and also for the boilers, in the form of so many I.HP. per ton. The boilers and the engines produced in one ship the same I.HP., and therefore to give a figure which showed so many I.HP. per ton for the boilers, and another figure, half the amount of the total machinery, did not give one the opportunity of seeing how many I.HP. per ton the engines alone would be; whereas had the weight per I.HP. been given instead of the I.HP. per ton, the difference in the two columns of figures would give

the weight per I.HP. of engines alone. The war-ship problem Prof. Biles.
naturally suggested two points of view. First, war-ships were produced to compete with other war-ships. It was, therefore, necessary to consider what war-ship builders were doing in other countries, and Tables were accordingly wanted which would enable judgment to be made of their performance, of the risks which were being run, and of the fineness of the margins compared with those of the British Navy. There was also the other consideration, that the engine and boiler, the installation of machinery in a war-ship, formed a steam-producing plant, and it could therefore be compared with the steam-producing plant not only in other navies, but also in the mercantile marine. There were a few instances in the mercantile marine in which the development of power per ton of weight was as good as it was in the Navy; and there was the curious fact that there were many builders in the country who would produce an installation of machinery which they would put either into a war-ship or a mercantile ship. In the mercantile ship there would be very common firemen, very common engineers, who were not in any way men possessing any superior qualification. That machinery would do its work day by day. It would, for instance, run across the Channel, and work for three or four, or perhaps five or six hours, under forced draught. It would stop at the end of its journey, after having gone all the way at full speed, and it would cool down as best it could, and start again the next day, doing it all without having the reputation of giving any trouble. On the other hand, the same builders would put a similar installation into a war-ship, and it was common knowledge that those war-ships, with practically the same installation, had the reputation of not doing very well. That led to a consideration of the cause. The only difference he could perceive was that in the human element; and that again led to the consideration of what was the difference between the engineers in the Navy and those in the mercantile marine. It appeared to him that the difference could only be, that in the mercantile marine the engineer did practically as he liked on board ship, while in the Navy he was dominated by the naval officer. That was necessary to some extent for the purposes of discipline, but he thought it was a subject for the serious consideration of the naval officer whether that domination was not too great for the efficiency of the machinery—whether the calls made upon the engineer to do what the naval officer wanted him to do from a disciplinary point of view were not too great for that purpose; and whether the

Prof. Biles. engineer officer should not have a greater independence than he had at the present time under the disciplinary domination of the naval officer on deck. He thought that perhaps there was more want of efficiency in the engineering plant of the Navy from that cause than from any other.

Dr. White. Dr. W. H. WHITE felt that naval architects had been showing themselves rather too largely in the discussion. He would not say a word but for the feeling that there were certain things that he might say that could not be well said by his friend and colleague, the Author, who had kept his Paper strictly within the lines of marine engineers' work. Particulars had been given by the Author as to the production of steam in boilers, the development of power in engines, the consumption of coal, and other matters which were of the greatest interest to those engaged in the design and manufacture of propelling-machinery for ships; but little, or nothing, had been said by the Author with reference to the utilization of power to the speed of ships, the choice of propellers, the causes influencing their efficiency, and the effect upon engine design which must arise from changes in speed and methods of propulsion. All the points which the Author had touched upon were points for the marine engineer, and it was a matter of very great satisfaction that so many marine engineers of eminence had taken part in the discussion. It was, however, a matter of some disappointment that they had not heard expressed, in a place where discussion was of the freest, and where reply was possible, some of the points which they had been accustomed to see discussed very fully in the technical press. It would have been an advantage to the Author in replying if those points had been brought into the discussion, so that he might deal, at least, with some of them. The Paper as it stood gave, as Dr. Kennedy had said, a great deal of information, but he did not think that it was the Author's intention in writing the Paper to tell all he knew; he still kept something to himself. The Paper could not have been kept within workable limits if the other policy had been adopted; and he knew that the Author would be in a position to tell Dr. Kennedy that his knowledge extended farther than would appear from the Paper itself on some of those points to which attention had been very properly drawn. The period with which the Author had dealt was one which had been most critical in the history of marine engineering. It had been a period during which he personally had been most keenly interested in war-ship design. Looking at the figures given in the Paper,

one thought of many of the difficulties and struggles, and, he thought he might say, some of the successes that had been achieved. In the Navy, during that time, there had occurred the extended use of forced or induced draught, a very considerable increase in steam-pressures, the introduction of the triple-expansion engine, the practical abandonment of horizontal engines in favour of those of the vertical type; a considerable increase in the rate of revolutions and piston-speed, a considerable increase in the speeds of ships, and a large economy in coal consumption. All these points appeared from the Tables, but they were all points which had an enormous effect upon war-ship design and propulsion all over the world. The Author's account of Admiralty practice represented not merely what had been done by himself as Engineer-in-chief, by his colleagues, and by his predecessors in office; but it represented and embodied the work of the leading marine engineering firms in the country, who, subject to the conditions laid down by the Admiralty, were continually producing, not merely engines, but designs for engines which were adopted in H.M. service. He thought that some of the differences which had been referred to in regard to the variety of practice in connection with engines and boilers, during the period set forth in the Tables, were only reasonably to be expected, when it was remembered that such a large number of engineering firms had been engaged in producing the machinery. He well remembered one special case—he did not say it was a strictly representative one—which occurred about twelve years ago, when the "Mersey" class, of which particulars were given in the Paper, was being designed. At that time his friend, Sir James Wright, was Engineer-in-chief, and he had adopted the course of fixing the limits of space and weight, and fixing what he conceived to be the essential conditions to be fulfilled in the design in regard to the quality of materials, the factors of safety for various parts and matters of that nature. Invitations had been sent to a number of the leading firms in the country, asking them to say what, within those limits of space and weight, they would be prepared to do in the development of power and in the consumption of coal. That invitation had been responded to by a number of firms. Their designs had been perfectly independent, and from amongst them had been selected that which was adopted for the "Mersey" and "Severn," which were amongst the first ships designed on the principle of adopting forced draught in the boiler-room. War-ship machinery, whilst it had its special features, owed very much to mercantile practice and experience—and no one was disposed to minimize that for a moment—especially Dr. White.

Dr. White. in regard to the use of increased steam-pressures, the introduction of the compound, and then of the triple-expansion engine. Those were only examples that might be multiplied. He thought it might be fairly claimed that the benefit had not been altogether on one side, and that the practice in war-ship machinery had also had a considerable influence upon much that had been done in the mercantile marine. As an illustration he might mention the use of forced draught in war-ships. He did not want to discuss the question whether forced draught had been carried too far or not in any particular instances, but he should like to point out that its use in H.M.'s ships had had a very marked effect upon the development of methods of assisted or mechanical draught in merchant ships during the last ten or twelve years. It was a notable circumstance that, in the statements made by Mr. Gross with reference to the development of power per square foot of heating-surface for continuous steaming at sea with the Ellis-Eaves system, results were claimed which compared very closely with the highest performance obtained with forced draught in H.M.'s ships on comparatively short trials. He thought he was right in saying that in the practical working of the Howden system at sea the development of power per square foot of heating-surface in the boilers had been stated at from $1\frac{3}{4}$ to 2 square feet per HP., which again would be seen not to compare unfairly with the maximum results mentioned in the Paper as obtained with forced draught for short periods. The point he wished to make was that the change of practice in H.M.'s ships had had a great influence upon mercantile practice, and had led many able and ingenious persons to consider the introduction of methods of assisting draught and of obtaining greater power from a given weight or size of boiler in association with economy of coal. Again, the successful employment of quick-running engines with moderate stroke in war-ships had its influence in the mercantile marine. He remembered being on the trial of the "Parisian," with the late Dr. Kirk, many years ago, when he allowed the engines to "get away," and they made 85 revolutions with 5-foot stroke and a piston-speed of about 850 feet per minute; the ship flying light and everything running at its best. In those days that was thought to be a very remarkable performance, far in excess of the condition under which ships then worked at sea. In the interval piston-speeds and revolutions had been increased, and results were now commonly obtained which, a few years ago, would have been thought undesirable or impossible. He could not help thinking that the experience of the Navy had largely

influenced progress in that direction. But while engineering practice in war and merchant ships had much in common, there were special limitations in war-ship machinery design which could not be got away from. It was to be remembered that war-ships were essentially fighting-machines, that they were built to carry armaments, to carry various methods of protection involving large weights of material, and the whole arrangements of the machinery had unavoidably to be subordinated to the preservation of fighting qualities. Of that there were many excellent examples in the diagrams, and it was hardly necessary to dwell upon it. From the examples of the arrangement of boilers in a battle-ship shown in the "Ramillies" diagrams, it would be seen that the stokeholds were placed fore and aft, and the longitudinal extension of the boiler-rooms was thus compressed. The explanation of that was that as she was a ship of great beam, it was possible to get an arrangement of coal and stokeholds favourably disposed in the breadth of the vessel. Before and abaft the machinery-spaces there were situated huge armoured enclosures containing the heavy guns. Every foot added to the length of the machinery-spaces in such a case involved an enormous weight of protective material, because it meant an extension of the armour to cover that length. In fact the arrangement of machinery, boilers and coal, was largely governed by the consideration of what lay above it in the way of protection and armament. There were ships in the Navy in which, immediately above the boiler- and engine-rooms, an armoured citadel stood, containing turrets in which very heavy guns were mounted, that had to be supplied with ammunition; there the engineer had perforce to accept conditions which he would be willingly free from, but it was of the essence of the design that that disposition of the armament should be provided for. Taking, on the other hand, first-class cruisers with protective decks, as in the case of the "Royal Arthur," there were greater possibilities in length, but considerably less beam than in the battle-ships, and there was the protecting deck existing throughout the length. There the best possible combination which could be made included athwart stokeholes and athwartship coal-bunkers. Going to the engine-room, it would be seen that to maintain the desired length of stroke in a vessel of moderate draught, an armoured enclosure was built surrounding the cylinders, and giving facilities for protection, ventilation, and all matters affecting the working of the machinery. Those were only instances that could be multiplied indefinitely, showing that in a war-ship the fact that she was a fighting-machine

Dr. White.

Dr. White. governed everything that had to be done both by the marine engineer and by the naval architect, increasing immensely the difficulties of both. Criticisms had often been made upon the arrangements of the machinery and boilers in war-ships which entirely ignored that governing condition, and he ventured to say that if some of the ardent critics were themselves placed in the unfortunate position of having to meet those difficulties, they would find it no easy task to provide solutions immensely superior to those which Admiralty experience had led the responsible designers to adopt as the best under all the circumstances. He did not say that Admiralty practice was incapable of improvement; he only said that it was a very desirable thing in dealing with any piece of mechanical work to assume that the man or men who were responsible had some reason for the method to which they ultimately came, and that they did not do what had been done out of pure wantonness. There was one other fact that he desired to state. It was a popular idea that the marine engineer was a "good man struggling with adversity" when dealing with the machinery of war-ships. Adversity was personified by the naval architect: he was always pressing and limiting and saying, "No, you shall not—this is all you shall have," and the marine engineer—poor, patient soul!—never complained, but always accepted everything that was offered. That idea was of course perfectly ridiculous. In all steamship design the essential condition of success was the harmonious collaboration of the naval architect and the marine engineer. He had had the honour of serving, since he had been Director of Naval Construction, with three Engineers-in-Chief, and—he said it in the presence of the Author with the greatest pleasure—from first to last there had never been any difficulty or difference of opinion whatever between them. Every point that had arisen had been dealt with by them conjointly, and they had only the common object of producing the best vessel to meet the stipulated conditions. The first of those gentlemen he had already mentioned, Sir James Wright, a man who had lived through marine-engineering from its commencement in war-ships, and who quitted work after he had served the Admiralty forty years. During that time Sir James Wright lived for the service in which he was employed, and although he was now enjoying well-earned rest, he, no doubt, looked with the greatest sympathy on what his successor had to face and to bear. The second was his dear friend, Mr. Richard Sennett, a man with whom he had been associated from his student days to the time of his death—a man whose professional ability

was beyond dispute, but whose courage and enterprise had often been misunderstood—who attempted great things, and did many great things, and who in some quarters had been spoken of as if, because he tried to go beyond precedent and experience, he was therefore a fanatic or a fool. Mr. Sennett was a man who by what he had done and dared had helped the cause of marine engineering in many ways, and in a manner that had yet to be fully realised. As the Author was present, he would say nothing with regard to him, but would only ask the members to believe that Mr. Durston was too modest to say what he might about his own work, that he had confined himself to a bare statement of fact, and that he was not above learning in any school where there was anything useful to be taught. Dr. White.

Mr. Miers Coryell remarked that to appreciate the Belleville boiler an engineer must see it in all the phases of furnace conditions while working at sea, and then after a voyage in preparation for the next one. He knew of no fire-room work so easily performed and so little fatiguing to the stoker, nor where the work could be so readily systematised, he might say disciplined, to advantage; the grates were covered with thin fires always, and the consumption was regulated by the charges being made more or less frequently according to the necessity. The activity of the fires was regulated by the opening more or less of the ash-pan doors, which were the draught regulators. The water-level was maintained by the feed-water regulator which automatically controlled the delivery of the pumps; at the same time none of the usual water-level gauges were omitted and were always in sight, and indicated in the same manner as upon other boilers. The automatic feed-water regulator was not at first well received by engineers; but his experience was that it was absolutely reliable and of great importance as an attachment to a boiler carrying a comparatively small amount of water. Light furnace charges, more or less frequent according to the required expenditure of steam, together with the assured steady alimentation, corresponding with the vaporization, were essential features to produce the best results in any boiler. The speed of the feed-pumps varied with the speed of the main engine, and the steam was never shut off from the pump while there was fire in the furnace, so that the pump not only varied in its strokes but might stop altogether to proceed again when the main engine moved. The purification of the feed-water was perfect, and the sediment was deposited out of reach of the tube-surface. By the action of the Belleville separator the steam was delivered dry at all times, whether the Mr. Miers Coryell.

Mr. Miers Coryell. vessel were rolling or pitching, however violently. To test its control over its steam-making power, that is to say, its safety against undue pressure under conditions that might occur at any time on a voyage, he had tried an experiment—with steam at 250 lbs. per square inch on boilers, the engine working at full speed, a pressure of 220 lbs. per square inch on the piston, and the fires in full activity. The engine had been suddenly stopped, by working the given appliances, and the steam-pressure had risen in five minutes to only 260 lbs. per square inch on the boilers, and in fifteen minutes to 265 lbs., remaining constant at that pressure. Again, under the same conditions as above, except that the engines had been started astern, the boiler-pressure had risen only 5 lbs. in five minutes, remaining constant at that point. As to economy and efficiency he had found them quite equal to those of the best constructed Scotch boiler, which had proved itself in his experience to be free from the necessity of even trifling repairs or adjustments at sea or in port, and from the clogging of the draught passages at sea. Every Belleville boiler was tested to 800 lbs. per square inch upon each detail, and could therefore perfectly safely carry 400 lbs. steam-pressure, and at any pressure salt water alimentation was not injurious. He recognised the wisdom of introducing the Belleville system into the Royal Navy, as it possessed many advantages in durability, in weight and in space occupied, and also in its ability to use any steam-pressure desired.

Mr. Henwood. Mr. E. N. Henwood said that the machinery of British war-ships, apart from the deplorable paucity of stokers—in itself a very serious matter—was open to criticism in many and various directions. With regard to the matter of speed, the Author had shown satisfaction at the fact that various war-ships had proved their ability to maintain, without any special effort, a high percentage of their natural-draught power, on time trials of a maximum duration of seventy-three hours. All that could be deduced from that was, that the ships were able to cruise along without disaster, at say, half speed, or about 10 knots an hour under natural draught. He maintained that any system of forced or induced draught would lead to no better results, because it did not dispense with the inherent defects of hand-firing, involving severe and exhausting labour, great waste and inefficiency. The only remedy for the evil was to replace the solid fuel by liquid and to feed the furnaces automatically, thereby maintaining an unvarying pressure of steam for full speed for virtually an unlimited period. Liquid fuel possessed other advantages, such as economy in quantity and space, 1 ton of oil doing the work of 4 tons of coal,

saving of labour, dispensing with stokers, removal of all danger of spontaneous combustion, and avoiding smoke, soot and ashes. Its inherent safety and non-inflammability in bulk, facility of shipment under all conditions, on land or at sea, and its ability to effect perfect combustion were greatly in its favour. The principal objection to the introduction of the system seemed to lay in the fact of England's control of coal supplies. Russia was fitting some of her war-ships of the first class for oil-fuel, and doubtless other nations would do so also; perhaps then the British Authorities would awake to the fact that they, if they wished to equal others in speed and steam endurance, would have to do likewise. Mr. Henwood.

Mr. DAVID JOY said that among the many subjects which had been treated in the Paper, two especially had fallen within the limit of his experience: first, that of water-tube boilers which the late Daniel Adamson called in ridicule "pipulous boilers" as against the Lancashire boiler, and which the Admiralty were taking up so largely. He had had, some years ago, a considerable experience with the Howard boiler, which was found to give good results so long as it was not hard driven, but it had failed when it had been put on board ship. Two ships had been sent to sea fitted with it, and both had been lost. A ship had been built by the Barrow Engineering Company of 600 tons displacement, with engines of 200 I.HP., and the greatest possible care had been taken in the design of a modification of the Howard boiler. The results of the first trial had been satisfactory, but the second trial had been attended by nothing but accident. The boilers had failed, filling the stokehold with steam to suffocation, and the ship was towed home. A record of all the results, however, showed that the water-tube boiler, maintaining anunfailing all-round circulation, was a very economical boiler, but the circulation was very uncertain and liable to great irregularities, and, if not kept up, a very little variation in the firing of one or other side of the same furnace would drive the water into a condition of effervescence from that side to the other, the evacuated side being immediately subject to be burnt. This had been proved to have been the case in the damaged water-tube boilers of the s.s. "Propontis," one of the earliest of the installation of true water-tube boiler. Mr. Joy.

With regard to the weight of the rapidly reciprocating parts, in consequence of the speeds being now very largely increased the reduction of the weight of these parts became of great importance. At the Institution of Naval Architects, Papers had been read and illustrated by models, to show how the vibrations were set up in a steamer, by the rapid reciprocations of the unbalanced parts,

Mr. Joy. and further to indicate how they might be prevented or neutralized by balancing or even by adjusting the positions of the weights.[1] These exhibitions, however, had tended rather to point out that the direct way to treat the subject was to reduce the weights, by dispensing with as many of the reciprocating parts as possible, owing to the difficulty of balancing complicated combinations of movement, such as the motion link of an ordinary link gear. Many engineers, retaining the weights, had endeavoured, in the general design of the engine, to obtain the effect of an all-round balance. In this respect, the quadruple-engine had found favour, and the engines to which he had referred, and of which drawings were on the table, were quadruple engines. He had received the assurance from the builders of ships and engines, that the ship was entirely free from vibration at the highest speed. He had treated the valve-gear with the view of diminishing the weight of the reciprocating parts, and had succeeded with a much simplified design of gear in reducing the number of parts to such an extent as to result in a saving of between 60 and 70 per cent. of the weight of reciprocating machinery.[2]

Mr. Durston. Mr. A. J. DURSTON, in reply, said that Sir Edward Reed, in some flattering remarks on the Paper, had referred to the increase of piston-speed in recent years. For that, with its accompanying lightness of machinery, he thought they were largely indebted to his late friend and predecessor, Mr. Sennett. That gentleman's work had been spoken of by Dr. White in terms with which he fully concurred. Engineers used as large a stroke as the design would allow. As Mr. Thornycroft had observed, engines were certainly lighter with the increased speed of revolutions. The cylinder ratios used in the Navy were not so large as in the mercantile marine, for the naval ship was generally run at a comparatively low power. She performed all long distances at comparatively low powers, and the best results with regard to economy were, he believed, always obtained at between 50 and 70 per cent. of the natural-draught power. On either side of that point economy fell; in one case by not having sufficient expansion, and in the other by having too much, and condensation affecting the result. With regard to the battle-ships "Barfleur" and "Centurion" and cruisers, weight had been added to their boilers and engines, as at the time it was considered, and rightly so, that those ships would have to steam much greater distances than a squadron of

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[1] Trans. Inst. Naval Architects, vol. xxxiii., 1892, p. 213.
[2] *Ibid*, vol. xxxv., 1894, p. 430.

battle-ships. The distances on the Pacific and China stations were much in excess of those run either in the Mediterranean or in the Channel. For future progress, he agreed with Mr. Yarrow—and other engineers were no doubt of the same opinion—that improved design and workmanship, stronger materials, more perfect combustion of fuel, further increased speed of engines and higher pressures of steam must be looked to. With regard to the latter, as far as past experience showed, as pressure of steam had been increased more HP. from a given unit of heating-surface had been gained. As far as the Navy was concerned, the triple expansion-engine would still serve for considerably higher pressures, although the engine might be, and had in many cases been, divided into four cylinders—that was by dividing the low-pressure cylinder into two. Mr. Durston.

The consumption of fuel had been referred to by Mr. Seaton, and was a very important matter in the consideration of the Admiralty; but most of the trials that were made for periods of less than twenty hours had for some years past been disregarded, because so much variation came in over shorter periods. At the end of the Paper several trials over long periods were referred to. Since the Paper had been written, an account had been received of three ships: in the "Spartan," a second-class cruiser, 6,777 I.HP. had been maintained for a run of seventy-two hours, or 96 per cent. of the natural-draught power, producing an I.HP. from 2·3 square feet of heating-surface. The consumption of fuel had been 1·96 lb. per I.HP. per hour. The second case was that of the "Resolution," a battle-ship. There the run had been for forty-eight hours, and the I.HP. had been 8,085, or 90 per cent. of the natural-draught power. The consumption had been 2·1 lbs. per I.HP. per hour. In both cases the engine-room crews had been in three watches, and it had been reported from both ships that they could have maintained that power for any time as long as the coal would last. The "Ramillies," another battle-ship, had also developed for thirty-four hours 8,111 I.HP., or 90 per cent. of her natural-draught power, on a consumption of 1·97 lb. of coal per I.HP. per hour. The "Endymion," in which Mr. Seaton was much interested, had also kept up its character as an economical ship. He might observe that these results were something beyond laboratory experiments.

As to the present position of forced draught in the Navy, of which enquiry had been made by Sir Edward Reed, the present rule was that engines were designed for a certain power at natural draught, which might be called 100; and for a cylin-

Mr. Durston. drical boiler the forced-draught power was made 20 per cent. in excess of that, namely 120. For continuous steaming as long as the coal would last, not less than 60 per cent. of the natural-draught power was to be developed. If less than that was obtained, inquiries were instituted. It had been shown in the Paper that in many instances nearly 100 per cent. of natural-draught power had been obtained over long distances —over such periods that they might say it could have been continued as long as there was any coal in the ship to burn. In action two watches of stokers went below into the engine-rooms and stokeholds. If one watch could produce nearly 100 per cent. of the natural-draught power, it was not an extravagant assumption to make, provided the boilers were clean and the engines properly adjusted, that 20 per cent. in excess of the natural-draught power could be readily produced for a short spurt. He thought that was not overstating the case, he was pretty confident that more would be done, notwithstanding Prof. Biles's bad opinion of the naval engineers and of the peculiar discipline said to obtain in the Navy. He was afraid he could not accept the statement. Whatever that gentleman had said about the naval engineer or about naval discipline applied to himself and to his colleagues.

With regard to the change of type of boilers, the Admiralty had come to the conclusion for some time past that by increasing the pressures in cylindrical and locomotive boilers very much would not be gained, and that it was necessary to turn to some type of boiler that contained less flat and thickly-stayed surfaces. Certain forms of tubulous boilers had shown themselves thus adapted for the purpose of utilizing the higher pressures, and after consideration and investigation of many sets of boilers in actual service, the Belleville boilers had been decided to be put into the "Terrible" and the "Powerful," the largest cruisers. A set had previously been ordered to be placed in the "Sharpshooter." Those boilers were doing very well indeed, and many of the engineer officers (who were not easily persuaded as to the merits of a new thing) who had seen the boilers at work had been much impressed with their ease of management, including ready means for keeping heating-surfaces clean while under way. But in addition to ease of management it was, of course, necessary to have facility for repairs and examinations. That had led, in large ships at all events, to a comparatively large diameter of tube. In tubulous boilers small tubes were thought to be very suitable, and they were certainly extensively applied in torpedo boats and ships of the torpedo flotilla. Three British types of

tubulous boilers were now in use in the Navy: there was the "Speedy," built by Messrs. Thornycroft; the "Daring," built by the same firm; and the "Hornet" type, by Messrs. Yarrow; and those were being repeated in many other boats. In the "Ferret" and other torpedo-boat destroyers boilers of the Normand type had been fitted, and in a few months it was hoped that several other types of tubulous boilers, British, American, and French, would be passing successfully through their trials. The Admiralty did not care what the nationality was, so long as the boiler was a good one. Mr. Durston.

With that introduction of the Belleville boiler and the Thornycroft boiler there had also been introduced automatic feed-apparatus, upon which engineers, some few years ago at all events, had looked with some suspicion; but, so far as experience had shown, the apparatus had been found to answer very satisfactorily and efficiently; and if it continued to do so, the reduction of the anxiety on the part of the man in charge of the stokehold, who would then be able to give more time to the firemen, would be appreciated. As to steam-pressures, Mr. Sampson had expressed a hope that they would not be limited. Pressures as high as 210 lbs. per square inch were being used in some engines; but in the case of the Belleville boiler the pressure in the boiler was from 50 to 60 lbs. in excess of that used at the engines. As he had before indicated, the pressures would, no doubt, be still higher in the future. The manner in which the materials stood would have to be followed, and a change of material might be necessary with a change of pressure.

He agreed with Mr. Seaton that the limit of power from any boiler, whether tubulous or otherwise, was the quantity of heat transmitted through a unit of heating-surface with safety. The Table towards the end of the Paper had been referred to by Mr. Thornycroft, who had desired some corrections to be made. The weights there given for boilers were for cold water; in the Tables of the Appendix, however, in every case the weight was for hot water. The powers of the "Daring" and the "Ferret" required a slight alteration. They had been inserted before the official record was received. The figures 4,300 for the "Daring" should be 4,400, and for the "Ferret" 4,500 should be 4,774. It would be observed that the figures in the last column were not very materially altered, and they gave a very fair measure of the efficiency of the respective types. The excessive heating-surface of the "Speedy" in the same Table had been complained of by Mr. Thornycroft, but he had used that same excessive heating-surface

Mr. Durston. in producing a certain figure of merit, in which it had been used as a divisor. As to priming, he could only say that in the "Speedy" two forced-draught trials were discontinued on account of it. It was the leakage of sea-water through the condenser-tubes that had caused the boilers to prime so violently that the trials had been discontinued. That opinion had been supported by Mr. Thornycroft when he spoke of a reservoir that was fitted in the "Geyser" with some other apparatus especially provided against priming. He understood that there was a reason for the existence of that reservoir. Putting that on one side, however, he was glad to say that the "Speedy" was doing very well with regard to economy. With the introduction of a higher pressure of steam, and with the tubulous boiler, very economical results had been obtained from the "Speedy's" machinery. He concurred in preferring steel tubes in water-tube boilers, as they were strong enough to resist the internal pressure when considerably over-heated. On that ground they were preferred in cylindrical and locomotive boilers. They were of more uniform material than Staffordshire iron, which had been used before, and they would stand the rolling in the tube-plates better, which was an important point in their favour. They also resisted leakage equally well. Another point was that the boiler was all of one material.

As to the systems of accelerated draught, as in the case of sails, the days of trusting to funnel-draught had passed. The fires and men must each have a good supply of air under all conditions of climate and atmosphere. So far as his experience had shown, the most compact system was that known as forced draught, which embodied a closed stoke-hole with fans supplying the air to it and the fires. The chief objection to that system was the closed stoke-hole, the air-tight casings, the double doors, and the air-locks accompanying them for ingress and egress. Next in order came the induced draught with fans in the funnel, and, in addition, fans for ventilating the stoke-hole. Having open stoke-holes, air-locks, doors and screens could be dispensed with, and, as had been stated in the Paper, there was a greater economy of fuel with that system. Why, he did not know, nor, he believed, was it known to those who carried out the experiments. There was more uptake work, of course, with induced draught. Besides those two systems, there were those known as the "Howden" and the "Ellis-Eaves." Those systems involved, in addition to the other two, the provision of air-heating apparatus, in the shape of a number of tubes. All these various appliances had been care-

fully considered, and the conclusion arrived at was that no advantage could be gained in their adoption for war-ship machinery, as neither system, as far as could be ascertained, had yet an installation in existence which in actual work could give so much I.HP. per ton as that of the forced draught. Another point was the doubtful advantages of those two systems. The air-heating system would only come in at high powers, and not at the low powers used on ordinary service. As Dr. White and Mr. Seaton had remarked, the Admiralty did not make changes without purpose. He and his colleagues had had the hearty co-operation and criticism of the machinery contractors as well as of the naval architects; and their brother engineers and officers afloat, both by their work at sea and by their criticism, served them at the same time. They invited criticism, but it must be expected that there would be some piquancy in it. In acknowledging the manner in which his Paper had been received, he did so on behalf of his colleagues as well as of himself, for without their constant good-will and helping energy, their chief could do but little. Mr. Durston

Sir Robert Rawlinson.

Sir ROBERT RAWLINSON, President, was sure that the members present had been pleased to listen to the interesting discussion which had taken place on the Author's most valuable Paper. He could assure the meeting that there were many people outside who would have been glad to have had the advantage of the information given within these walls. An American gentleman had said to him, "Oh, yes, it is very generous of you to give us all this information; but I beg to tell you that we know it. There is nothing new. You tell us what you have done, but you do not tell us what you are doing now." Sir Robert Rawlinson individually was glad that there was that reservation. People would get to know what was being done in due time. The question of steam-power as applied to ships of war was one of the most important questions of the day. Ships of war were built, and he assumed that builders constructed them for use. If he could have his way they should be burnt, but then there would have to be by consent a general burning all over the world. The millennium, however, had not yet arrived. He could only say that it was most generous on the part of the Admiralty to permit its officers to bring forward and to illustrate the work they were doing with the nation's money—that information being thus made available for merchant shipbuilders, as also for all workers in iron and steel; and it was an enormous advantage to discuss before the Institution the properties of the material used, and the way in which it was used. Machinery now went upon the principle of

Sir Robert Rawlinson. quick revolution to attain a high speed. All machines that were built to move rapidly were built to wear out rapidly, and would have, therefore, to be renewed from time to time. No doubt improvements would be introduced, and nations who engaged in that kind of work must take advantage of these, in order to keep their place in the world. He begged to thank all those who had taken part in the discussion, and who had added to the information given by the Author of the Paper.

Correspondence.

Mr. Isherwood. Mr. B. F. Isherwood, Chief Engineer, United States Navy, thought the Paper intimated to the engineer that, under the present conditions of practice, he was at the limit of his resources in the production of power relatively to weight of materials used. A halt was thus called pending a new departure, and the enquiry was: Could the weight and space of the present machinery be further materially lessened by any practicable modification, or by any changes?

As the Paper did not deal with principles, but was confined to pure statement of facts, all that could be said concerning it was the expression of the highest appreciation of its practical value, and the hope that it might be supplemented by other similar Papers furnishing the exact dimensions of the vessels and machinery, including waste spaces at cylinder-ends, diameter of piston-rods, and drawings of the propelling-screws. Also, that the Author would describe, in as much detail as possible, the trial performances of these vessels, supplying average indicator-diagrams. His official position enabled him to obtain the precise figures, and he could do his profession, his Government, and the public, no greater service than to give this useful information to the world.

Returning to the Paper under discussion, Mr. Isherwood would endeavour, as germane to the question, to show how, in his opinion, the ratio of weight to power in the case of marine machinery could be still further lessened without too radical a departure from current practice, and without going beyond the methods and means at present in vogue. Multiple-cylinder steam-engines, including in that term the compound, the triple-expansion, the quadruple-expansion, &c., had superseded single-cylinder steam-engines, because they were practically necessary for the use of steam of continually-increasing pressure, while such higher pressure steam

was required for increased economy of fuel and increased efficiency of the mechanism. The steam-pressure was limited by the boiler which furnished it, and not until the plant and the material for the high-pressure marine boiler were had, could the multiple-cylinder engine compete successfully with the single-cylinder engine. For the low-pressures formerly employed, the latter was superior in all points. The engine had to follow the boiler, and could only advance *pari passu* with it. There was no economy in the multiple-cylinder types of engine over the simple one-cylinder type, when the engines were equivalent and used steam of the same regimen. That was, supposing the initial pressure of the steam on the piston to be the same, the measure of its expansion to be the same, the condenser back-pressure to be the same, the stroke of the pistons to be the same, the number of strokes made in equal time being also the same, the diameter of the large cylinder of the multiple-cylinder engine to be the same as the diameter of the single cylinder of the simple engine type, the valve-gear, steam-jacketing, waste spaces, &c., being likewise the same in all. Although the type of engine as such was sensibly without influence on the economy of the steam for any given regimen, the use of high-pressure steam was impracticable with the single-cylinder engine, owing to the enormous maximum strains it produces upon the mechanism, while, with the multiple-cylinder engine, these strains could be reduced to any desired extent by the simple multiplication of the cylinders. This fact constituted so valuable a practical feature, peculiar to engines of the multiple-cylinder type, that it had caused their adoption almost universally to the exclusion of engines of the single-cylinder type. For the single-cylinder type, each cylinder formed a complete engine, receiving steam directly from the boiler and exhausting it directly to the condenser. An engine of the multiple-cylinder type, however, was composed of as many cylinders (each successive cylinder being of greater volume than its immediate predecessor) as intervened between the reception of the boiler-steam by the valve-chest of the small cylinder and the exhaust from the valve-chest of the large cylinder into the condenser, the steam passing in succession through all the cylinders from small to large, undergoing an expansion in each succeeding cylinder in the ratio of the volume of the immediately preceding cylinder to its own volume, without regard to the action of any cut-off valve which might be placed on the succeeding cylinders. From this peculiarity had been derived the popular names "double-expansion or compound engine," "triple expansion," "quadruple expansion-engine" &c., each added

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Mr. Isherwood. cylinder of greater volume producing an independent expansion of the steam.

The same reduction of maximum strain due to the multiplication of cylinders in engines of the multiple-cylinder type, could not be produced by dividing the single cylinder of the simple engine into as many cylinders as the equivalent multiple-cylinder engine. Hence, as boiler-pressures were increased, it was found indispensable not only to increase the number of cylinders for a given power, but to adopt the multiple-cylinder type of engine in order to produce the greatest practicable reduction of the maximum strain in the case of the single-cylinder type. Evidently, however, the substitution of the former for the latter type of engine considerably increased (for the same power produced from the same regimen of the steam) both the weight and bulk of the engine in relation to that power, so that to the extent of such increase it was a decided retrogression, but it was necessary at any cost of weight and space, because the economic advantages of the high-pressure steam thus made realisable, were of sufficient importance to counteract the objection and still have a great margin of gain.

The principal advantages and disadvantages of steam of higher pressure over steam of lower pressure were, firstly, That, other things being equal, more power was developed per unit of heat produced by fuel; secondly, That more power was developed by an engine having the same dimensions of cylinder; thirdly, That, owing to the decreased dimensions of the cylinder, in the ratio of the increased pressure, an increased number of double strokes of its piston per unit of time became practicable, whereby a still greater power could be developed by the same engine; fourthly, In consequence of a smaller engine being thus required for a given power under given conditions, the weight and bulk of the engine alone were lessened with the increased pressure; fifthly, But, on the contrary, the weight and bulk of the boiler was increased, because the higher the steam-pressure the greater was the steam-temperature, and, consequently, the less economical would be the generation of the steam, owing to the necessarily higher temperature of the gases of combustion when leaving the boiler. Hence, the greater the pressure of the steam the greater would be the weight and bulk of the boiler to furnish steam for a given power developed by the engine. Also, the greater must be the weight and bulk of coal carried for steaming, with a given power, a given unit of time. The loss of heat by radiation from the external surfaces of both boiler and engine, was greater the greater the temperature of the steam. The loss of steam by

leakage past the pistons and the steam-valves was also greater the greater the pressure of the steam. Sixthly, That the condensation of steam in the cylinder due to the interchange of heat between the steam and the metal during a cycle of the engine, or one double stroke of the piston, was less, because, for equal measures of expansion, the fall of temperature in the steam was less for higher than for lower pressures, the condensation referred to being wholly due to the difference of temperature produced by the expansion of steam. An increased reciprocating velocity of the piston was accompanied by a lessened condensation in the cylinder, owing to lessened time required for making a stroke of the piston. Also, a decreased diameter of the cylinder was accompanied by an increased condensation in it, owing to the greater ratio which the inner aggregate surface of the cylinder had to the capacity of the cylinder when the diameter of the latter was decreased. In this manner, the gain due to the increased reciprocating velocity of the piston of the cylinder of less diameter might be neutralized by the loss due to the lessening of the diameter itself, only the difference for gain or loss was realizable. Seventhly, the principal advantage of higher pressure steam over steam of lower pressure was the increase in the measure of expansion with which the steam could be economically used. The causes limiting the measure of expansion were the boiler-pressure, the back-pressure against the piston, the pressure required to work the unloaded engine, the waste spaces at the ends of the cylinder, and the condensation in the cylinder due to the heat interaction between the metal of the cylinder and the steam (not due to the development of the power produced by the expanded steam alone after the closing of the cut-off valve). With any practicable initial steam-pressure, however, these causes prevented expansion from being carried for any practical engine beyond a comparatively moderate measure, which had already been reached, and in many cases exceeded, notably in triple-expansion pumping-engines, notwithstanding that the limiting causes of back pressure and waste spaces had been reduced to the possible minimum in them. Mr. Isherwood.

With the present marine cylindrical boiler the limit of pressure had been already reached, caused by considerations of size, strength, weight, difficulty and cost of construction, &c. The steam regimen, and the distribution of the pressure into different successive cylinders, had been carried as far as practicable, and could the pressure be increased there would not result any economic advantage.

There still remained a method by which the boiler-pressure

Mr. Isherwood. could be considerably increased without involving the loss due to the proportionally increased temperature of the gases of combustion passing into the atmosphere. Suppose the area of heating-surface now used to be divided into two, say, equal parts, and let the boiler be constructed as now, but with only one part of the present heating-surface, the remaining part being placed in a separate cylindrical shell called for distinction the heater, which communicated with the boiler by means of a pipe fitted with a check-valve. The feed-water was pumped into the heater and thence through the pipe and check-valve into the boiler. The heater was entirely filled with water and the tubes containing the heating-surface, no steam being in it. The gases of combustion from the boiler passed on their way to the chimney through the tubes of the heater. By this arrangement both boiler and heater were under the same pressure, but had not the same temperature. The temperature of the heater was entirely independent of the boiler pressure, and need not in any case exceed, say, 250° F., let the boiler temperature be what it might. With the rate of combustion at the maximum, the gases of combustion under these circumstances would pass into the atmosphere at the temperature of about 300° F., instead of about 900° and more, as at present with the maximum rate of combustion. A saving of about 25 per cent. of the fuel could thus be easily made by the lesser amount of heat wasted in the gases of combustion. The draught in this case would of course always be mechanically produced by "blowers," and the rate of combustion would be the same as at present. The boiler and heater combined would not exceed in bulk and weight the present boiler, because, owing to the greater economic vaporization with the heater arrangement, proportionally less grate- and heating-surface would be required for the production in equal times of the same weight of steam. The money cost of the coal, and of the firemen and stokers to handle it, would be reduced 25 per cent.; and the weight of coal carried in the bunkers, together with the space it occupied, would also be reduced 25 per cent.

There had been proposed, in order to reduce the weight and space now required for the cylindrical tubular boiler generally employed on board of steamers, to substitute for it some kind of pipe boiler. The space occupied by the present boiler would thus be considerably reduced, and the aggregate weight of the boiler and water would be reduced still more. The objections to the pipe boiler were its relatively less durability and reliability, the difficulty of locating leakages and of making repairs. The corrosion of its metal was very rapid, owing to the thinness re-

quired to produce the less weight; it could not be kept clean, that was, the exterior of its heating surface could not be swept of soot and ash, nor the interior of that surface kept free of scale. The presence of soot on the heating surface increased the rapidity of the corrosion, and lessened the economic vaporization; the presence of scale also lessened the economic vaporization, and accelerated the destruction of the metal by burning out. The hot gases of combustion could not be properly or uniformly distributed over the heating surface, so that a considerable fraction of the latter must remain inoperative, requiring a higher ratio of heating to grate-surface to reduce the temperature of the gases to the same limit as in the present boiler. The economic vaporization of the pipe boiler, whatever were its kind, must necessarily be considerably less than the economic vaporization of the cylindrical tubular boiler, that was to say, with equal ratio of heating- to grate-surface, and equal rate of combustion of the fuel, the pipe boiler would give greatly less weight of steam per lb. of fuel than the cylindrical tubular boiler. Even with 50 per cent. more heating- to grate-surface (the usual excess with pipe boilers), their economic vaporization was from one-tenth to one-eighth less, owing in part to the causes already pointed out; and, in addition, largely to the excessive leakage of air all along (from furnace to chimney) into the space occupied by the gases of combustion, which air, mingling with these gases, both reduced their temperature and carried off into the atmosphere the heat thus acquired. The bulk of air thus admitted and expanded by its acquired temperature transmuted into the work of its expulsion from the chimney a corresponding portion of the heat generated by the fuel. More grate- and heating-surface and more fuel would be required with the pipe boiler than with the cylindrical tubular boiler, so that very probably the gain in weight and space predicated on equal grate- and heating-surface and equal rate of combustion might prove illusory. Of course, the lesser economic vaporization entailed greater weight and volume of coal for the bunkers, more firemen and coal-heavers to handle it, and more money for the coal-purchase and for wages. In general, the best boiler at all points for a steamer, was the one which gave the largest economic vaporization. In one respect the pipe boiler (with the exception of the Belleville variety) had an incontestable superiority in its greater maximum rate of combustion. The cylindrical tubular boiler with 28 square feet of heating-surface to 1 square foot of grate-surface, was limited to the combustion of about 42½ lbs. of coal per hour per square foot of grate, which could not be exceeded without starting the tubes

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Mr. Isherwood. from their plates; whereas the pipe boiler, by reason of the curvature that could be given to its pipes, could burn with safety from 60 to 70 lbs. of coal per hour per square foot of grate-surface, a gain of about 50 per cent. in rate of combustion per square foot of grate-surface, but only equal per square foot of heating-surface. Its large ratio of heating- to grate-surface was otherwise favourable to excessive rates of combustion. Hence, for small vessels like torpedo-boats, steam-launches, yachts, &c., that carried but a very small quantity of coal in their bunkers relatively to the power developed by their engines, the superiority of the pipe-boiler was manifest, always excepting the Belleville boiler, whose rate of combustion, owing to its feeding conditions, was restricted to about 18 lbs. of coal per hour per square foot of grate-surface.

The reason why the present boiler was restricted to the rate of combustion, 42½ lbs. of coal per hour per square foot of grate-surface, was the fact that the temperature of the metal of the tubes for that rate and for the ratio of heating- to grate-surface employed, was so much greater than the temperature of the shell of the boiler (which was the same as the temperature of the contained water and steam), that the tube was forced through its plate by its increase of length due to its greater expansion. This effect could be avoided by increasing the ratio of the heating to the grate surface; every increase in this ratio allowed an increase in the rate of combustion on the grate. With three times the present ratio, that is, with a ratio of, say, 85 square feet of heating-surface to 1 square foot of grate, the present rate of combustion could be doubled with safety, or increased to 85 lbs. of coal per hour per square foot of grate-surface. The temperature of the metal of the tube when the latter was surrounded by water at constant temperature depended on the quantity of heat thrown upon it in a given time, the more the heat the higher the temperature, and *vice versâ*, for the absorption and giving out of heat by the two surfaces of the metal was a question of time, and to pass more heat in the same time required a proportionally increased "head of heat," that was, increased difference of temperature. By increasing the heating-surface more heat could be passed without increasing the temperature of that surface. The temperature of the metal of a tube, from end to end, was sensibly the same for any given set of conditions, owing to the rapidity with which heat was conducted from molecule to molecule between the external surfaces. The molecular conduction of heat within metals followed very different laws from their absorption and emission of heat. The idea that the leaking of the tubes when the rate of

combustion exceeded 42½ lbs. of coal per hour per square foot of grate-surface was due to a local overheating of the tube-plates and tube-ends was wholly discredited by every fact of boiler-engineering. Neither plates nor tube-ends showed any appearance of having been "burned," nor could the leakage be stopped by covering the one with patches and the other with ferrules. This leakage, which first appeared in some boilers of the British Navy when hard driven by forced draught, had only been avoided by reducing the force of the draught, that was, by reducing the rate of combustion, and by increasing the ratio of the heating- to the grate-surface, as first pointed out at the time by himself. These changes, in one direction or the other, had been continuous ever since. The announcement made when these leakages appeared, that they had been stopped by patching the plates and ferruling the tube-ends, and that these palliations were completely successful, was a total mistake; nothing of the kind occurred, and, in expressive American slang, the announcement was "too previous." Mr. Isherwood.

In respect to what might be called "mechanical efficiency" of the engine, the lessened pressure on the crank-pin and main-shaft journals of the multiple-cylinder engine, relatively to the pressure on the corresponding journals of the equivalent single-cylinder engine, prevented the danger and inconvenience of journal-heating, which rendered the use of high-pressure steam and high piston-speed in a single-cylinder engine so difficult and troublesome. Moreover, the greater the number of cylinders into which the power was distributed—the cranks being placed equidistant around the shaft—the less would be the unbalanced effect of the reciprocating parts of the engine in producing vibration of the hull. This, indeed, was the only way of effectively counterbalancing those parts in movement, and neutralizing the action of their *vis viva* on the vessel. By obtaining the power required for the pumping needed for the engine, from an independent auxiliary engine, thus disembarrassing the main engine from any adaptation on that account, the reciprocating speed of the pistons of the main engine could be carried to any extent consistent with effective lubrication of the principal journals. A considerable increase of economy and decrease of weight would be thus realizable. Engines of the largest power could be worked up to from 200 to 250 revolutions per minute, at which speed no steam-jackets would be necessary. At an infinite reciprocating speed of piston, the cylinder condensation due to the heat-interaction between its metal and the heat of the steam would be infinitesimal. There was no practical difficulty with

Mr. Isherwood. any desired lineal speed of piston. The change in the direction of the movement—the reciprocation—the bringing of the swiftly-moving masses to a state of rest and then setting them in motion in a reverse direction was the practically troublesome problem. The pumping referred to was that done by the air-pump, circulating-pump, feed-pump, and bilge-pump. The separate auxiliary engine working these pumps should be supplied with steam from a separate auxiliary boiler in which the pressure was carried from 25 to 30 lbs. per square inch above the pressure in the main boiler. The exhaust-steam from the auxiliary engine should be delivered into the main boiler supplying the propelling engine and not into any of the receivers of that engine. By this arrangement all the rejected eat from the pumping-engine was utilized in the propelling engine, the only heat disappearing being that which was converted into the work done by the pumping-engine, and lost by the difference of radiation due to the difference of temperature in the auxiliary and in the main boiler. The pumping-engine in this case could have simple cylinders using the steam without expansion, as no economic benefit would be derivable from using the steam expansively.

As regarded type of boiler, type of engine, and regimen of steam, there did not appear any probability of improvement. In one particular, however, the practical details of the engine could be economically much improved, namely, by the substitution of a slide-valve for the present piston-valve, which in marine triple-expansion engines was always employed for the small cylinder, generally for the intermediate cylinder, and often for the large cylinder. It involved not only enormous economic losses by reason of the excessive waste spaces at the ends of the cylinder caused by its use, but materially diminished the economy due to the measure of expansion with which the steam was used. Mechanically, the piston-valve, though of very old date, was still the best that had been devised. It was perfectly counterbalanced, easy to construct, and, when placed vertically, had no other friction than that due to its packing. It was durable, reliable, and could be employed with the highest pressures equally well as with the lowest, giving no more trouble than any piston of the same diameter. But these excellent qualities were bought by an appalling waste of steam. It had every mechanical virtue and every economic vice. It even caused a considerable increase in the cylinder condensation due to the heat-interchange between the steam and the metal, by enlarging, by means of the enlarged waste space at the cylinder-ends, the metallic surface undergoing variation

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of temperature. The great desideratum in practical marine engineering was a perfectly counterbalanced steam-valve for cylinders, that could be used with a waste space not exceeding, say, 5 per cent. of the piston-displacement as a maximum, instead of the waste space of from 15 to 25 per cent. required with the piston-valve. The economic loss due to waste space at the cylinder-ends increased rapidly with increase of the measure of expansion with which the steam was used, and with such large waste spaces as were needed for the piston-valve greatly restricted the measure of expansion with which the steam could be economically used with less waste space. Many persons held, but quite erroneously, that the injurious effect of the waste space at the cylinder-ends was obliterated by cushioning or compressing the back-pressure steam in the cylinder to the initial cylinder-pressure, so that the ratio of this space to the piston-displacement per stroke was immaterial when such cushioning was employed. The cushioning, much or little, did not in the slightest degree affect the dynamic performance of the steam; it slightly affected the economic performance beneficially, that was, to the extent of the heat absorbed by the metal of the cylinder from the compressed back-pressure steam during its compression, which heat was really obtained for nothing, as the work absorbed for the compression was exactly returned during the succeeding stroke of the piston. The compressed steam was worth exactly its weight of steam taken directly from the boiler, and would reproduce during the succeeding stroke of the piston exactly the work expended in its compression, let the regimen of the steam in the cylinder be what it might. In other words, the compressed-steam cost in the work of its compression as much as it is worth when filling the waste space, so that the injurious effect of this space remained the same whether there were cushioning or not, with the exception of the gain of heat just described.

With triple-expansion pumping-engines, fitted with any of the many modifications of the Corliss valve, giving waste spaces of from 2 to 4 per cent. of the piston-displacement per stroke, the indicated HP. was obtained for about 13½ lbs. weight of steam consumed per hour; while with the same engine fitted with piston-valves as applied on board steamers, the indicated HP. cost about 18 lbs. weight of steam per hour, both engines using the most economical measure of expansion for its own case, which was a greater measure for the pumping- than for the marine-engine. Here was an economic difference of one-third, measured by the pumping-engine performance, and of one-fourth, measured by the marine-engine performance, and, supposing it to be realized by

Mr. Isherwood. the marine-engine, the weight of the marine-engine boiler per HP. would be decreased nearly 25 per cent., an enormous decrease, and obtainable, as shown practically by repeated experiment, as the result of the mere substitution of valves of one type for valves of another type on the cylinders of the same engine. Not only would the weight of the boiler be reduced, but the space occupied by the bunker coal, and the weight of that coal itself, would be reduced in an equal proportion. The money cost of the coal, and the labour of handling it, would also be correspondingly reduced.

Whatever economy might be effected in the production of the indicated HP., as measured by the percentage of coal saved, extended for a steamer to the weight, space and cost of the boiler; to the weight, space and cost of the coal in the bunkers; and to the labour saved in handling that coal on board. Economy in the production of the power was, then, of greater consequence with a marine-engine than with a land-engine to the extent that the boiler, coal, firemen and coalheavers, were permanent parts of the displacement of the vessel and of the space within it.

On no subject could the mechanical ingenuity of the age be better applied than the invention of a steam-valve combining the merits of the piston-valve and of the Corliss valve and excluding the demerits of both. The designers of marine-engines should not be satisfied with any economy less than that obtained by land-engines. What had been done with the latter could surely be done with the former. There was here a possibility of greatly reducing the weight of the steam department of a vessel per HP. developed.

The question of proportional weight to power developed, in the case of the steam-machinery of vessels, must include boiler and coal as well as engine, for otherwise the answer would be greatly misleading. In a certain vessel a certain aggregate weight and space could be allowed for all the objects of the steam department, with the proviso that the coal be sufficient for maximum steaming for a given number of hours, which for a war-vessel should certainly not be less than ninety-six. The problem was to proportion the engine, boiler and coal to each other, so that at the maximum power the coal would last ninety-six hours. The weights compared with the power must be these weights of engine, boiler and coal. To compare only the weights of the engine and boiler with the power developed would be quite illusory, as it excluded the factor of time; there would remain to be answered the question: For how long? Where economy—that was coal—was sacrificed, a large development of power might be obtained from a small weight of machinery, excluding coal, but

obviously a still greater development would be obtained from the Mr. Isherwood. same weight of machinery could the steam produced by the boiler be more economically used by the engine. These very important points must be satisfactorily met before the present system of marine engineering could be said to have reached its limits as regards relation of weight to power.

The piston-valve as now applied, in addition to the enormous economic losses it entailed by reason of its excessive waste spaces at the ends of the cylinders, did not give the highest possible economic distribution of the steam. It cut off the steam too late in each cylinder, causing great losses by the consequent large "drop" and "gap" between succeeding cylinders, as shown by indicator diagrams, thereby much increasing the back pressure against the pistons. The steam should be cut off at not more than one-fourth of the stroke of the piston in the small cylinder, and sufficiently short in the other cylinders to make the pressure at the end of the stroke of their pistons but a few lbs. per square inch above the back pressure against those pistons. The capacities of the cylinders should be proportioned for such conditions. In a single-cylinder engine, the economy obtainable from expansion depended simply on the measure of the expansion; but in a multiple-cylinder engine this economy depended not only on the measure of expansion as a whole for the engine, but also on the manner in which that expansion was effected in each cylinder considered separately, and on the manner of transferring the expanding steam from one cylinder to another. With the same measure of expansion as a whole, a difference in the economy of 10 per cent. could be made with the multiple-cylinder engine by difference in the manner in which the steam was expanded in the different cylinders and transferred from one to the other.

A consideration of these points would easily show how the great difference was caused between the economy of the pumping-engine and that of the marine engine, both being of the same type and using steam of the same boiler-pressure, with the same vacuum in the condenser. Nor could equality of economy be obtained in the two cases by simply making the measure of expansion equal, the process of the expansion must be the same also, and with the same waste space at the cylinder ends. The less waste space with the pumping-engine allows the steam to be used much more expansively with economy than the greater waste space with the marine engine; there was, therefore, additional gain for the pumping engine by the difference.

The foregoing facts and inferences justified the statement that,

Mr. Isherwood. even with current practice, and without passing beyond the means and methods in daily use, the best marine machinery as now designed could be greatly lessened in the proportion of its weight to its power developed, and with an accompanying great increase in its economy of fuel.

Mr. Johnson. Mr. CHARLES M. JOHNSON, R.N., remarked that the advance in piston-speed in ships of the Royal Navy had been considerable during the past seven years, as the Author had shown; but except in the new torpedo-catchers (where it was over 1,200 feet) and a few torpedo-boats, 1,000 feet per minute had not yet been reached. In the merchant service the maximum was about 850 feet up to the present time.[1] For the fifteen years between 1870 and 1885, the advance was but small. The greatest speed at the earlier date was that attained in H.M.S. "Sultan," which reached a maximum of 646 feet per minute, a speed greatly in advance of the general practice of that day, and for many years after. At the later date only 700 feet per minute had been reached in H.M.S. "Impérieuse." At the present day the maximum piston-speed (in all but the smaller type of vessels) was a little over 900 feet. It was questionable whether any great advance on 1,000 feet per minute would ever be attempted in reciprocating engines of large size, as the racking strains were so great, and the tendency in shipbuilding appeared to be towards lighter scantlings. He remembered talking over this question some few years ago with the then Engineer-in-chief of the Navy, the late Richard Sennett, who was of opinion that the limit of piston-speed (maximum about 700 feet) had not nearly been reached, but that the limit of velocity in the propeller had very nearly been reached, and that in the future it was quite possible that early practice might be reversed, and engineers gear down to the screw instead of gearing up. But since that day a great deal had been learned about propellers, water-surface friction, form, periphery, &c., and the tendency now was towards less diameter, minimum area compatible with the absorption of the power developed by the engines, and a high velocity.

But the question of racking-strains and light scantlings still remained to be faced. Whether they would ever get rid of the former by the adoption of rotary instead of reciprocating motion, had yet to be determined, but there were plenty of existing engineers who refused to say "*non possumus*." The main difficulties to be over-

[1] He had only been able to find two ships in the mercantile marine which exceeded this speed, viz., the "Lucania" and "Campania," which had a piston-speed of 960 feet. Their immediate precursors, the "Teutonic" and "Majestic," had a speed of only 780 feet per minute.—C. M. J.

come in the rotary engine were well known. They were: efficient expansion of the steam, circumferential friction, and steamtight joints and pistons. That the change, if it came, would be welcomed by all engineers and shipbuilders was obvious, and it might be that all those difficulties would be overcome with the progress of science, the discovery of new metals, or of other properties (now unknown) in the metals already in use. Mr. Johnson.

The increase in boiler-pressures had been remarkable, and had been distinguished by sudden advances, succeeded by periods of rest, rather than by steady progression. For example, before and during the Crimean war, ships of the Royal Navy were being worked with pressures of from 5 lbs. to 10 lbs. per square inch in the boilers; but before that war was over pressures of 60 lbs. were being used, not merely in the gunboats specially built for that war (250 in number), but even in the large two-decked ships, fitted with high-pressure non-condensing engines. For years after the Crimean War, 30 lbs. was the limit of boiler-pressures in all large, and in many of the smaller, ships. About 1873 an advance was made, in the fast cruisers of that period, to 60 lbs.; and that pressure ran a steady course until about 1880, when a further advance to 110 lbs. took place. From 1880 slight increments of pressure occurred, culminating in a pressure of 155 lbs. Here, again, there had been a pause until, in the present year, another sudden jump had taken place to 200 lbs. in sundry torpedo-destroyers; while in the "Sharpshooter" 250 lbs. was the boiler-pressure.[1]

As the temperature of steam at 250 lbs. pressure (265 lbs. absolute) was about 406°, the difficulty of efficiently lubricating the internal parts would be very great with the present lubricants; and it was therefore desirable to discover a metal, or alloy, which would work without lubrication (other than that which the steam supplied), or to find a lubricant which would be efficient up to 500° or 600° temperature. Perkins's metal had done good service in small engines; but it had yet to be tried with higher pressures and drier steam. Would aluminium, or its alloys, furnish the metal required for piston-spring rings; or must they give up spring rings, and bestow greater care on, and use more delicate machinery in, the boring and finishing of the cylinders, furnishing them with deeper pistons, more accurately fitted? This seemed to be the direction in which modern engineering was moving; and should

[1] The initial pressure on the engines was 150 lbs., the steam passing through a reducing valve of very elaborate design.

Mr. Johnson. this advance come, higher pressures, faster piston-speed, and great reduction of friction within the cylinders might be looked for.

For higher pressures the tubulous boiler was apparently the best type; but its form would have to be modified to give greater results per lb. of coal, increased safety in working, and a considerable reduction of temperature in the escaping gases. Automatic feeding and stoking were also necessary to the attainment of more perfect results in all boilers, but especially in the tubulous type. The Belleville automatic feed was ingenious, but unscientific. The feed-pipes and fittings were all designed to stand a constant pressure of double that in the boiler, so that when this pressure was reached the feed-pump (practically) stopped, because the load on the pump, and the power in the cylinder, were in equilibrium. In consequence of this feature in the design, these pumps and fittings were abnormally strong and heavy, and were therefore not in harmony with modern naval practice.

Mr. Johnson appended a Table, in which types of machinery built for the Royal Navy were given in groups of years, as illustrating his contention.

Name of Vessel.	Date of Trial.	Piston Speed in Feet per Minute.	Weight on Safety-Valve.	Remarks.
Conflict . .	1848	272	10	
Dauntless .	1848	252	10	
Arrogant .	1849	333	5	
Algiers . .	1854	175	10	
Cornwallis .	1855	515	55	High pressure, non-condensing.
Hastings .	1855	390	65	" "
Meteor . .	1855	556	60	" "
Forth . .	1856	570	60	" "
Himalaya .	1856	399	18	Built for the P. & O. S. N. Co.
Aboukir . .	1858	405	20	
Arethusa .	1862	485	25	
Achilles . .	1866	440	25	
Bellerophon.	1866	600	30	
Pallas . .	1866	510	32	
Lord Warden	1867	569	31½	
Dryad . .	1867	446	32	
Spartan . .	1869	511	70	
Active . .	1870	523	30	
Dido . . .	1870	492	31	

Mr. Johnson.

Name of Vessel.	Date of Trial.	Piston Speed in Feet per Minute.	Weight on Safety-Valve.	Remarks.
Cyclops . .	1871	572	60	
Sultan . .	1871	646	30	
Devastation .	1872	500	30	
Amethyst .	1873	537	60	
Rupert . .	1873	504	35	
Rover . .	1875	548	70	
Bacchante .	1877	608	70	
Téméraire .	1877	604	60	
Iris . . .	1878	582	65	
Carysfort .	1879	588	60	
Nelson . .	1880	574	60	
Inflexible .	1880	615	60	
Amphion .	1884	618	90	
Agamemnon.	1884	536	63	
Collingwood	1884	665	90	
Impérieuse .	1885	698	90	
Benbow . .	1886	758	90	
Australia .	1887	865	130	
Sans Pareil .	1888	900	135	
Trafalgar .	1889	855	135	
Nile . . .	1890	846	135	
Anson . .	1890	693	100	
Blake . .	1891	712	155	
Hood . .	1892	858	155	
Circe . .	1892	784	155	
Blenheim .	1892	840	155	
Bonaventure	1893	950	155	
Ferret . .	1894	1,230	200	Torpedo-boat destroyer.
Powerful .	..	880[1]	260	Estimated steam-pressure 210 lbs. at engines.
Teutonic .	1889	780	180	White Star Company, Limited.
Majestic . .	1890	780	180	" " "
Campania .	1893	966	165	Cunard Company.
Lucania . .	1893	962	165	" "

[1] This is the "estimated" speed of piston; and unless the estimate be greatly exceeded in actual practice, the most modern man-of-war will scarcely be up to date as regards speed of piston.

Mr. McGregor. Mr. JOSIAH MCGREGOR said the Paper offered an opportunity for discussing points of divergence between Navy and mercantile design in the construction of machinery, the reasons for which had not always been apparent. One of the most important of these was pointed out by Sir Edward Reed, namely, the cylinder-ratios. Mr. McGregor had supposed that the revolutions mentioned in the Paper were those for forced draught, not for natural draught full power, and that in triple-expansion engines was the ratio of the high- to the low-pressure cylinder, only that was given, the intermediate-cylinder ratio being about the square root of the latter. It appeared thus, that the total cylinder-capacities were, for the triple-expansion engines, usually about eight times that of the high-pressure cylinder, while the best mercantile practice might be taken at about eleven; and as the reason for this did not appear on the surface, perhaps the Author could afford some information on the point. This was the more desirable as the compound-engine ratios of the Navy agreed very closely with mercantile usage, so that mere difference in the nature of the service did not appear to be the explanation.

The information as to boilers in the Navy was most interesting, and it was satisfactory to hear that the trouble experienced with tube-ends and scoriæ had been to a great extent overcome. With reference to the employment by the Admiralty of another class of boiler to the powerful cruisers now building, which had been so much commented on, Mr. McGregor would remark that though there was a great potentiality in the water-tube boiler, there were a number of difficulties connected with their use in sea-going vessels that had yet to be satisfactorily overcome. About twenty years ago he had had much experience with them, and could only say that at that time they fell far short of expectations and were always replaced by boilers of another type. He therefore expected to hear some substantial reason for their adoption in the Navy, but in this he was disappointed. The only one appeared to be ability to get up steam quickly, which Mr. McGregor hardly thought of such importance as to dictate the class of boiler to be used. The Author remarked (p. 29) that "in view of the ability of these boilers to maintain a high rate of steaming for considerable periods, their tactical and other advantages, it has been decided to fit them on two first-class cruisers." In reference to the first of these reasons, it was surely not maintained that they were superior to the tank types. As to their tactical advantages, that of getting up steam quickly was the only one apparent, and as to the "other advantages" Mr. McGregor thought the Institution

would be glad if the Author would enumerate them. One of the chief reasons for employing boilers of this class was the high pressures obtainable, but as the machinery of the Navy limited the pressure to well within the ability of tank-boilers this was of no account. Turning to the disadvantages, it was admitted that they were infinitely more liable to the greatest of all evil sin boiler-working, priming. This evil was not only a most wasteful one in fuel, but it was one that required constant care and tact, especially when such small quantities of water were involved. And when it was borne in mind that little more than a tendency to prime prevented the engines from working at their full power, he should have thought, especially in such important vessels as the "Powerful" and "Terrible," that the slightest superiority in the matter would have indicated the class of boiler desirable. Mr. McGregor.

The contingencies of avoiding as far as possible the risk, in such a position as chasing an enemy or escaping from one, of finding that at the critical moment the engines would not work at more than a fraction of their power, should have been considered of the first importance. This tendency to prime was the real reason why boilers of this class were always worked with little more than natural draught, and required such greatly increased grate- and heating-surfaces. But when this was overcome to the same extent as in tank-boilers they could not fail to commend themselves. Until this was the case, however, to bring forward the matter and to discuss their merits without special reference to priming, and to adopt them on a large scale in most important vessels without reassuring information on this point, which was completely wanting in the Paper, was, in Mr. McGregor's opinion, unwarrantable.

As regarded durability, the Author said that was a matter for experience, but it was evident that, unless the tubes were of some thickness, then durability would be small, and parts of the tubes of water-tube boilers had been found to be peculiarly liable to corrosion. In the case of the Royal Navy, little or no advantage in the matter of weight appeared to be claimed, so he was at a loss to account for the change.

The Tables of weights were interesting, but it was much to be regretted that the uncertain and varying element of spare gear, amounting in some instances to a considerable fraction of the weight of the engines, should have been included in boiler weights, as it rendered all those figures on their application to boiler questions perfectly useless. He hoped therefore the Author would eliminate this item from the weight of the boilers before the Paper appeared in the Minutes of Proceedings.

Mr. Soliani. Mr. NABOR SOLIANI, of Castellamare, suggested one or two points for consideration, as to the advantages of single-ended boilers in comparison with those having double ends. The Author included the possibility, with the former, of spreading in turn the wear due to steaming for auxiliary purposes over the whole of the boilers, rather than confining it to one or two of them. Mr. Soliani would add, in support of this view, that on board ships of the Italian navy, having only main double-ended boilers, it had been found wasteful of fuel to use one of them for auxiliary steaming. However, the difficulty had been avoided by shortening the grates to half their length (by covering them partially with bricks) in the boiler that was temporarily chosen for auxiliary steaming, and the result has been so far satisfactory. He would like to know whether, in the opinion of the Author, there was any objection to that practice. The Author, in his Paper on "The Transmission of Heat through Tube-plates" (Trans. of the Institution of Naval Architects, 1893), hinted at the advantage of roomy combustion-chambers, and mentioned the experiments he was going to make to ascertain whether any benefit would accrue by shortening the boiler-tubes and increasing by equal length the combustion-chambers. As a great believer in roomy combustion-chambers, both with regard to efficiency of combustion and preservation of tube-ends, Mr. Soliani would like to know the Author's experience on this point.

Mr. Spanny. Mr. SPANNY, President of the Technical Commission of the Austro-Hungarian Navy, by permission of the Imperial Royal War Department, contributed some particulars of the warships built in Austria-Hungary during the last ten years. In consulting the Table (pp. 110, 111) it would be well to take into account the following circumstances:—

(1) In the Austro-Hungarian Navy "natural draught" meant chimney-draught only. (2) Battle-ships and cruisers had to use for cruising-speeds natural draught exclusively, but might work the fans for ventilating the stokeholds. On the occasion of the twenty-four hours' trials, which followed the manœuvres, and in cases of emergency in ordinary times, it was also permitted to close the stokeholds, or ashpits, and to work on air-pressures of not more than 15 millimetres (0·59 inch) of water. (3) Gunboats and torpedo-boats used air-pressures of not more than 100 millimetres (say 4 inches) in closed stokeholds, and 50 millimetres in closed ashpits. (4) The great convenience of a fair amount of forced draught applied under the foregoing conditions, the reduction of internal lubrication to a minimum, and the circum-

Mr. Spanny.

stance that the feed-water circulated through heaters, which partly expelled the oil contained in it, made the use of ferrules entirely unnecessary. They very rarely had trouble from leaky boiler-tubes. (5) At contractors' trials there had occasionally been used higher air-pressures than those above mentioned. In the contracts last placed the air-pressure permitted for forced-draughts trials was limited, for tank-boilers to 40 millimetres (for two hours' trial), and for locomotive-boilers to 150 millimetres for closed stokeholds: the corresponding pressure allowed for closed ashpits (for three hours' trial) being 70 millimetres. (6) With reference to the rare use of artificial draught in battle-ships and cruisers it might be mentioned that their boiler-tubes were not less than 70 millimetres ($2\frac{3}{4}$ inches) in external diameter. (7) For providing water for "make up" purposes only evaporators were employed. Further there were collecting-drainpipes arranged, conducting from the main- and auxiliary-engines to the hot wells and to the auxiliary-condensers, so diminishing the loss of water. In exceptional instances the ships were allowed to have fresh water into their double-bottom. In this way the feed-water, which was generally distilled, remained almost free of sediment and salts, and could not cause any serious trouble in the boilers. (8) In all the boilers the combustion-chambers were subdivided. (9) The valve-gear consisted mostly of the ordinary link-motion; but Marshall's and Joy's valve-gear had, in certain cases, been adopted with success. (10) The larger engines with horizontal cylinders were fitted with independent air-pumps driven by auxiliary-engines.

[TABLES.

Mr. Spanny.

MACHINERY OF AUSTRO-

Post Nos.	Ship.	I.HP. on Trial, Natural Draught.	Air Pressure.	I.HP. on Trial, Forced Draught.	Air-Pressure.	Weights.		Surfaces.	
						Machinery Complete.	Boilers.	Grate.	Total Heating.
			Inch.		Inch.	Tons.	Tons.	Sq. Ft.	Sq. Feet.
I	Tegetthoff[1] . . .	7,237	..	8,824	0·45	799·1	504·3	538·2	19,978·0
II	Kronprinz Rüdolf[2].	4,062	..	5,130	1·25	924·6	438·1	662·0	19,360·0
III	Kronprinzessin Stephanie[2] . . .	4,437	..	7,930	1·77	907·1	453·9	680·0	17,500·0
IV	Type Küstenvertheidiger (coast defence)[3]. . .	expected 5,916	0·6	expected 8,381	1·57	835·6	449·4	568·3	15,769·2
V	Type Kaiserin Elisabeth[4]	6,252	0·6	8,532	1·57	866·0	486·5	557·5	16,461·6
VI	Kaiserin und Königin Maria Theresia[4].	5,817	..	9,776	1·77	986·6	575·5	662·6	18,387·5
VII	Type Panther[5]. .	4,437	..	6,113	2–2·3	559·0	304·1	426·0	12,620·0
VIII	„ Komet[6] . .	..	..	2,958	3·5	131·4	65·3	96·8	5,119·3
IX	„ Trabant[7] . .	..	..	3,746	2·4	175·2	103·9	166·6	7,223·5
X	„ Planet[7] . .	..	..	3,053	1·4	155·5	96·0	162·5	6,088·8
XI	„ Satellit[7] . .	..	..	4,141	1·57	164·9	99·5	187·8	8,413·0
XII	Pelikan[8] . . .	3,832	..	..	..	394·5	241·2	272·9	9,989·0
XIII	Type Köriös[9] . .	..	..	1,163	1·67	58·1	35·1	64·5	2,863·0
XIV	„ Habicht (torpedo-boat) . .	..	..	952	1·28	29·4	16·5	40·7	1,797·2

[1] Vertical three-cylinder triple-expansion engines with twin-screws, running about 125 revolutions per minute at full power. Stroke, 3 feet 3⅜ inches; piston-speed, 820 feet per minute; boilers of the single-ended return-tube type, eight in number, with three furnaces in each; load on safety-valves, 156 lbs. per square inch; boilers placed in four compartments, arranged back to back against a middle-line bulkhead.

[2] Vertical compound engines with twin-screws. "Kronprinz Rüdolf," two cylinders ("Kronprinzessin Stephanie" three high-pressure, two low-pressure cylinders), running about 72 revolutions per minute at full power ("Stephanie" about 100 revolutions). Stroke, 3 feet 9$\frac{5}{16}$ inches ("Stephanie" 3 feet 3 inches); piston-speed, 540 feet per minute ("Stephanie" 650 feet); boilers of the single-ended return-tube type, ten in number, with three furnaces in each; load on safety-valves, 75 lbs. per square inch ("Stephanie" 100 lbs.); boilers placed in four compartments, arranged back to back against a middle-line bulkhead.

[3] Vertical three-cylinder triple-expansion engines with twin-screws, running about 140 revolutions per minute at full power. Stroke, 2 feet 11$\frac{7}{16}$ inches; piston-speed, 827 feet per minute; boilers placed in four compartments, five together; three of them double-ended with six furnaces, and two single-ended with three furnaces in each; load on safety-valves, 156 lbs. per square inch.

[4] Horizontal direct-acting three-cylinder triple-expansion engines with twin-screws, running about 120 revolutions per minute at full power ("Maria Theresia" 121·2 revolutions). Stroke, 3 feet 5⅜ inches; piston-speed, 827 feet per minute ("Maria Theresia" 835 feet per minute); boilers of the double-ended type, four in number, with six furnaces in each; load on safety-valves, 156 lbs. per square inch ("Maria Theresia" 156 lbs. per square inch); boilers placed in two compartments.

[5] Vertical two-cylinder compound engines with twin-screws, running about 128 revo-

HUNGARIAN WAR-SHIPS. Mr. Spanny.

I.HP. per Ton.				I.HP. per Square Foot of Grate.		Heating-Surface per I.HP.		Boiler-Tubes Material.	Speed in Knots.
Machinery Complete.		Boilers.							
Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.	Natural Draught.	Forced Draught.		
						Sq. Feet.	Sq. Feet.		
9·1	11·4	14·3	17·5	13·4	16·4	2·7	2·3	Steel	15·50
4·4	5·5	9·2	11·7	6·1	7·7	4·7	3·7	„	15·07
4·8	8·7	9·8	17·5	6·5	11·6	3·95	2·2	„	15·93
7·1	10·0	13·1	18·6	10·4	14·7	2·7	1·9	„	expected 17·50
7·2	9·8	12·8	17·5	11·2	15·3	2·6	1·9	„	19·65
5·9	9·9	10·1	16·9	8·8	14·7	3·2	1·9	„	19·35
7·9	10·9	14·5	20·1	10·4	14·3	2·8	2·1	„	18·40
..	22·5	..	45·3	..	30·5	..	1·7	„	21·29
..	21·3	..	36·0	..	22·4	..	1·9	„	20·04
..	19·6	..	31·8	..	18·8	..	2·0	„	19·39
..	25·1	..	41·6	..	22·0	..	2·0	„	21·86
9·7	..	15·8	..	14·0	..	2·6	..	„	17·80
..	20·0	..	33·1	..	18·0	..	2·4	„	10·46
..	32·4	..	57·6	..	23·4	..	1·9	„	21·21

lutions per minute at full power. Stroke, 3 feet; piston-speed 768 feet per minute; boilers of the double-ended type, four in number, with six furnaces in each; load on safety-valves, 135 lbs. per square inch; boilers placed in two compartments.

[6] Vertical three-cylinder triple-expansion engines with single-screw, running about 250 revolutions per minute at full power. Stroke, 1 foot 11⅝ inches; piston-speed, 984 feet per minute; boilers of the locomotive type, two in number, placed in one compartment; load on safety-valves, 170 lbs. per square inch.

[7] Vertical three-cylinder triple-expansion engines with twin-screws, running about 280 revolutions per minute at full power ("Planet" 256, "Satellit" 275·4 revolutions per minute). Stroke, 1 foot 8¼ inches ("Planet" 1 foot 8 inches, "Satellit" 1 foot $7\frac{1}{16}$ inches); piston-speed 955 feet per minute ("Planet" 853, "Satellit" 904 feet per minute). Boilers of the locomotive type, four in number; load on safety-valves 185 lbs. per square inch ("Planet" 170 lbs., "Satellit" 185 lbs.; "Planet" half-water bottom). Boilers placed in two compartments.

[8] Vertical three-cylinder triple-expansion engines with single-screw, running about 128 revolutions per minute at full power. Stroke, 3 feet 3⅜ inches; piston-speed 840 feet per minute. Boilers of the double-ended type, two in number, with six furnaces in each; load on safety-valves 156 lbs. per square inch.

[9] Monitors on the River Danube:—Vertical three-cylinder triple-expansion engines, with twin-screws running about 363·5 revolutions per minute at full power; stroke, 1 foot 3¾ inches; piston-speed 954 feet per minute. Boilers of locomotive type, two in number, load on safety-valves 185 lbs. per square inch.

[10] Vertical three-cylinder triple-expansion engine with single-screw, running about 350 revolutions per minute at full power. Stroke, 1 foot 3⅝ inches; piston-speed, 919 feet per minute. Boiler of the locomotive type; load on safety-valves, 170 lbs. per square inch.

Mr. Westgarth.

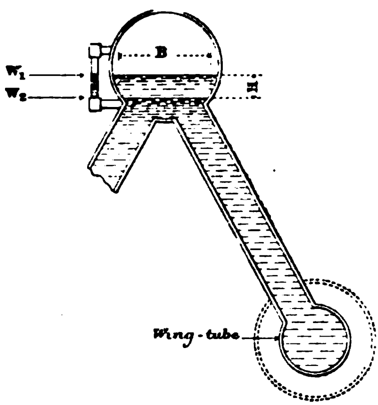
Mr. T. WESTGARTH, as a builder of marine engines for the mercantile marine, fully appreciated the wonderful results obtained by the designers and manufacturers of Navy engines, both as to beauty of construction, light weight, and high trial-trip results. He thought, however, that too much importance was attached to these points. No doubt builders of engines for the merchant service made every effort to get good trial-trip results, but it was equally certain that the owners of vessels and the public did not attach much importance to these trials, but waited for the result of voyages in actual service, and it appeared to him that the same rule should obtain for vessels in the Navy. The machinery of modern mail vessels would certainly not be considered satisfactory by anyone if voyages across the Atlantic, and in some cases even to Australia, could not be made at full speed, without stoppage, and with the ordinary engine-room staff. It was very doubtful whether many of the vessels in the Navy could comply with such conditions. In case of an enemy desiring to land troops in India or Australia, and sending them by such vessels as those belonging to the North German Lloyd, the Hamburg-American Company, or by the Russian Volunteer Fleet, could any British cruisers, although nominally of higher speed, make the passage in less time or even in equal time? This ought to be possible. He considered that the full-speed trials of war-vessels should be over long distances, in some cases even to Australia or China, so that the officers of the Navy, as well as the public, might be satisfied that the vessels really could and would do the work for which they would be required in time of war. It might be said that such long voyages at full speed would cause unnecessary straining of the vessels or their machinery, and unnecessary exertion on the part of the crew, but no such excuses would be entertained for a moment with regard to vessels of the mercantile marine. It might also be said that the cost of these long voyages at full speed would be very great, but he was quite sure that the extra expense would be well earned in the experience and practice which would be gained, and he did not think the public would object to such an expenditure.

One reason why it appeared to be so difficult to get continuous long runs at full speed from vessels in the Navy was that the machinery was made too light and the available space too small. He was quite aware that the designers of the machinery were handicapped in both these particulars by the naval architect, also that a more liberal allowance of weight and space for machinery would probably result in material reduction in the trial-trip

speeds of the vessels, but he did not think that the speed on an ordinary voyage at sea over a long distance would be at all reduced by the adoption of these suggestions, especially for the class of cruisers and vessels intended to make long voyages, and for foreign service. Mr. Westgarth.

Mr. C. HUMPHREY WINGFIELD observed, in reference to the statement on p. 28 of the Paper that the small quantity of water in boilers of the "Speedy" type entailed considerable attention to feeding, that at first sight this seemed a self-evident proposition, and it had been so frequently stated that it was perhaps worth while to examine it more closely. A stoker's duty, with regard to feeding his boilers, was to keep the water in sight in the gauge-glass, and not to allow it to exceed the highest permissible working level. Any difficulty he might experience in performing this duty must depend upon (1) the time required to evaporate the water contained between the upper and lower limits of water-level, W_1 and W_2 (*Fig. 1*); (2) the time occupied by the feed-pump in pumping sufficient water to fill this space (marked H); and (3) the amount of water available from which to pump. If the same depth, H, were taken in all the boilers considered, the amount of attention required would depend upon the mean horizontal section, of width B, of the water above bottom of gauge-glass. As a matter of curiosity Mr. Wingfield had made a rough estimate, by scaling the drawings issued with the report of the Boiler Commission, of the amount of water corresponding to a height of 5 inches in the gauge-glass of the Navy type boiler of the three vessels "Royal Sovereign," "Sybille," and "Edgar." Taking the same depth of water in the "Speedy," and assuming $3\frac{1}{2}$ HP. for every cubic foot evaporated per hour, he found that if the feed were entirely shut off, the water would remain visible only three minutes longer in the Navy type than in the "Speedy's" boilers, notwithstanding the great difference in the total weight of water contained in them. It would be seen at once that if the weight of water in a "Speedy" boiler were increased, say by enlarging the wing tubes, as per dotted lines, to any extent, the difficulty or Mr. Wingfield.

Fig. 1.



Mr. Wingfield. otherwise of keeping the water in sight would be absolutely unaffected.[1] Some extra attention was of course necessary with water-tube or any other boilers, when subdivided into a considerable number, if, as was usual on steamships, the supply of feed-water was practically limited to the quantity of steam condensed from the main engines. In the "Speedy," for example, if the water in seven out of the eight boilers had been ½ inch too high, that in the eighth boiler would have been seven half inches, or 3½ inches, too low, and possibly some reserve water might be pumped in. If with this extra amount in the circuit the seven boilers were allowed to become each ½ inch short, the eighth boiler would be 3½ inches too high, unless the extra water accumulated in the hot-well. Of course the probability of so many boilers being low at the same time was exceedingly remote; still on this account some extra attention was at first given to the feed on the "Speedy," but this slight trouble was afterwards entirely overcome by the use of the Thornycroft automatic feed-regulating gear. Then, again, with regard to priming. It was now generally recognised that priming depended largely on the quality of water used. That at Sheerness was so bad in this respect that the authorities at the dockyard either distilled their water or imported it from Chatham, as experience had shown that Sheerness water invariably caused priming. When mixed with salt water it was even worse, yet this was the water with which the "Speedy" ran her natural draught trial. It might be of interest to note that it was the practice of leading contractors, when conducting trials at Sheerness, to ship their feed-water from London. It was true, as stated in the official report, that there was "slight priming" from time to time; but experience with the older type of boilers appeared to indicate that they could not have steamed at all under similar conditions. He wished to guard himself from being supposed to say that other types of water-tube boilers were necessarily better in this respect than the Navy type. Careful experiments, which had been described in a Paper read before the Institution of Naval Architects, and which might also be found on p. 399, vol. 57 of "Engineering," proved that water with which a

[1] If what happened when the water went out of sight were considered, there was no comparison between the two types of boiler, since in the case of the Navy boiler there was danger to be shortly apprehended, whereas in the "Speedy" type a boiler under high pressure had been known, when neglected, to boil away all the water down to the level of the top of the wing-tubes, after which it gave way, not by a disastrous explosion, but by some of the tubes melting.

"Speedy" type boiler would just work without priming had to be Mr. Wingfield diluted with its own bulk of good fresh water before it could be used under similar conditions in a boiler in which drowned tubes were fitted. When boilers primed a false level was often shown in the gauge-glass, and possibly the evil was often aggravated by consequent mismanagement of the feed. Such an apparatus as Mr. Thornycroft's automatic feed gear, which admitted water just when wanted, instead of when it appeared to be required, often had the effect of stopping incipient priming.

Mr. Wingfield gathered, from p. 30, that when the induced-draught system gave better results than were obtained with closed stokeholds, this was due to better stoking. Sir Edward Reed had suggested piston-speed as a subject for discussion, and asked whether it was best obtained by a long stroke or a high speed of rotation. In nearly every case the answer was unquestionably by the latter means. A high rate of revolution was an advantage in many ways; a high piston-speed was in many respects a nuisance. Unfortunately the one could not always be obtained without the other, so a compromise had to be made. Comparing two engines with the same mean effective steam-pressures and of the same power, if their revolutions per minute were the same, but one had a longer stroke than the other, the former would have a greater piston-speed, a smaller piston, and, therefore, less load on the bearings. It would probably also have less clearance, but the weights of the two engines would not materially differ. If, however, the two engines had different speeds of rotation, the one having the higher number of revolutions per minute would be the lighter; it would have less initial condensation, and weight would also be saved in propellers, shafting and fittings.

The causes which limited piston-speed were of interest. If it were too high, the motion had to be arrested very suddenly at the ends of the stroke. The piston was brought to rest by two forces:—(1) Compressed steam; (2) pressure on joints and bearings transmitted through connecting- and piston-rods. It was commonly assumed that a great deal could be done with the first of these, and some writers spoke of "cushioning," as if the whole of the area *e c d f* in *Fig. 2* represented energy available for stopping the piston. A glance at *Fig. 3*, however, in which the effect of the pressure on the other side of the piston was indicated, showed that the shaded area *a b d* represented all the energy really available. The force due to cushioning was partly cancelled and only acted from *b* to *a*, instead of from *c* to *a* as in

Mr. Wingfield. *Fig. 2.* The vertical dotted lines in *Fig. 3* showed the effective pressure moving the piston in the direction of the arrow.

It was convenient to represent the force required to bring the piston to rest without compression as a pressure which gradually increased till it attained a maximum of P lbs. per square inch of piston area.

$$P = \frac{W\,S\,R^2}{70{,}584} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where W = weight of reciprocating parts in lbs. per square inch of piston;
S = stroke in inches;
R = revolutions per minute.

Cushioning would diminish the force P which was transmitted through rods and joints; but since it had just been shown to be of

Fig. 2.

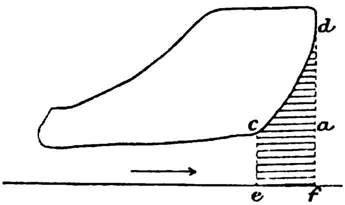
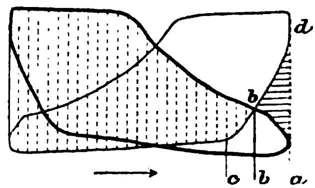


Fig. 3.



so little use in naval engines with late cut-off, it might be neglected for the purposes of this investigation. It would be seen from (1) that as the speed increased, the strains on piston- and connecting-rods increased at a rapid rate, and a speed would soon be reached at which their necessary proportions became abnormal, and beyond which the increased stress due to their own weight counterbalanced any gain due to increased scantlings of rods, &c. The limiting speed therefore was one at which, with proportions met with in ordinary practice, the strains and pressures due to inertia could be conveniently taken up by the sections and surfaces provided for them without undue stresses or trouble from heating or knocking.

W did not vary greatly, and the maximum admissible value of P might also be taken as sensibly constant for engines of similar type.

Transposing (1)—

$$R = \sqrt{\frac{70{,}584 \times P}{W\,S}} \quad . \quad . \quad . \quad (2)$$

Mr. Wingfield.

putting $$K = \sqrt{\frac{70,584\,P}{W}}$$

this became $$R = \frac{K}{\sqrt{S}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The value of K might be found from successful practice, and (3) would then give the revolutions at which engines of similar type might be expected to run equally well. K was low for battle-ships, and gradually increased as the type of engine approached that of torpedo-boats. Thus (roughly)—

For the engines on p. 32	K = 700
,, ,, 34	K = 730
,, ,, 36	K = 800
,, ,, 38	K = 850
,, ,, 40[1]	K = 950
,, ,, 44	K = 1,145
,, "Barham" and "Bellona"	K = 1,143
,, "Sharpshooter" class	K = 1,145
,, "Grasshopper"	K = 1,272
,, "Rattlesnake"	K = 1,315

It was interesting to compare with these the values of K for torpedo-boat destroyers and for torpedo-boats, as these probably represented the highest speeds at which it was practicable to run safely even with light machinery.

For the "Daring"	K = 1,555
,, "Ferret"	K = 1,540
,, "Hornet"	K = 1,650

Of course it needed not to say that when the value of K was so high as in the last examples, the greatest possible care in design and manufacture was necessary to ensure satisfactory results. With proper proportions, however, even these speeds might be exceeded; and for the 2nd class Thornycroft torpedo-boats, K was as high as 1,800. If the weight of reciprocating parts could be reduced, higher speeds and lighter engines would be possible, and aluminium slightly alloyed with copper had been proposed on the Continent as a material for pistons. For many reasons it appeared to him an unsuitable material; for instance, it rapidly lost strength when hot.

Many years ago he had designed an arrangement of air-cushioning for absorbing and giving out the kinetic energy in a slide-valve towards the end of its stroke, and a similar arrange-

[1] Except for the "Barham" and "Bellona."

Mr. Wingfield. ment had been applied by Mr. Willans to the pistons of his single-acting engines. A modification of this plan would perhaps render higher speeds possible.

Mr. Durston. Mr. DURSTON, in reply to the correspondence, said the long statement of Mr. Isherwood, much of which was of an elementary nature, required but brief comment. The complete information requested, it was regretted, could not be furnished. The proposal of a compound boiler was not, in the Author's opinion, a workable one; and many of the remarks regarding water-tube boilers were not supported by recent experience. Mr. Isherwood's announcement that the leakage of tubes in boilers had not been stopped by the use of the cap-ferrules was not in accordance with experience as regarded the boilers of British vessels. The reduction of clearance-spaces had been well known for many years as a desirable thing to be sought after. The practice of shortening the grates, referred to by Mr. Soliani, was one that had been often used in the British Navy, and no objection was seen to it. Experiments had been made to ascertain whether increased economy would be obtained by lengthening the combustion-chamber in a boiler, but the results obtained were practically identical with those obtained prior to the alteration. The practice of fitting independent air-pumps in the Austrian Navy was not one that commended itself to British engineers, and, possibly, the short period of trial (two hours) might account somewhat for the little trouble experienced with leaky boiler tubes. In answer to Mr. Johnson's remarks, it might be stated that no difficulty had been experienced with steam up to 220 lbs., without internal lubrication, in vessels of the torpedo-boat class.

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27 November, 1894.

SIR BENJAMIN BAKER, K.C.M.G., Vice-President,
in the Chair.

The discussion upon the Paper on "The Machinery of War-Ships," by Mr. A. J. Durston, occupied the evening.

4 December, 1894.

SIR ROBERT RAWLINSON, K.C.B., President, in the Chair.

It was announced that the several Associate Members hereunder mentioned had been transferred to the class of

Member.

ARCHIBALD MILES ANDERSON.
JAMES PATTEN BARBER.
SAMUEL GEORGE HERBERT BARFIELD, D.Sc.
HENRY GEORGE BOYCE.
WILLIAM BURCH.
ERNEST MACARTNEY DE BURGH.
EDWARD KEVILLE DIXON, M.E.
WILLIAM ALFRED ECKERSLEY.
THOMAS MILNES FAVELL.
FRANCIS ROBERT JOHNSON.
JOHN KYLE, Jun.
ARTHUR HERBERT MEYSEY-THOMPSON.
JOHN CURWEN POTTINGER.
CHRISTER PETER SANDBERG.
OCTAVIUS JAMES SHEDLOCK.
GEORGE RICHARDSON STRACHAN.
THOMAS SUMMERS, B.Sc.
STEPHEN HARDING TERRY.
GEORGE ADOLPHUS TIMME.
HENRY WEBSTER, B.E.
WALTER JAMES WEIGHTMAN.

And that the following Candidates had been admitted as

Students.

JAMES ANDREW.
WILLIAM TITTLEY BATCHELOR.
JOHN GILCHRIST BENNETT.
HENRY WALTER LAURIE MCWILLIAM BOURKE, A.R.S.M.
RICHARD BROOKS.
AMOS BURTON, Jun.
GEORGE JAMES CAMPBELL.
WILSON STORY CARR.
REGINALD BONHAM CARTER.
ALEC FLEMING CHURCHILL.
WALTER CLAPHAM.
HAROLD EUSTACE COAD.
ARTHUR CHARLES COLLIS-ADAMSON.
STEPHEN WILLIAM DASSENAIKE.
FRANKLIN BONAMEY HANKEY DOBREE.
HARRY DUNCAN DORMOR.
WILLIAM DU BOIS DUDDELL.
THOMAS EDMUND ETLINGER.
ARTHUR CECIL FELLOWS.
ARTHUR AUBREY FRANCIS.
RALPH ERNEST GIBSON.
GEORGE COCHRANE GODFREY, B.A.
FREDERICK AUSTEN HADOW.
JAMES WILLIAM HAY-ELLIS.
GEORGE MARKHAM HAYTON.
DAVID GAY HILL.
VALENTINE ALBANY HILLMAN.
GEORGE TREMENHEERE HUNTINGFORD.
HENRY WESTERN HUTCHINSON.
ALFRED ERNEST JACKSON.
ALEXANDER HOPE JAMESON, B.Sc.
FREDERICK TALFOURD JONES.
THOMAS GILBERT JONES, B.Sc., Wh.Sc.
CHARLES WARRE KAY.
ARCHER DAVE KEIGWIN.
DAVID WATSON KINMONT.
ARTHUR BERTRAM KNIGHT.
HERBERT LAPWORTH.
FREDERIC WINFRIED LA TROBE-BATEMAN.
CECIL LIGHTFOOT.
DAVID ERNEST LLOYD-DAVIES.
JAMES HARRY LOVELL.

Students—continued.

Charles McCreath.
Charles McFadzean, Jun.
Rienzi Walton Macfarlane, A.R.S.M.
Norman Alexander Harris McIver.
Charles Oreti McKellar.
Frank Maeers.
Angus Cameron Hooper Maguire.
John Frederick Marshall.
Mortimer Hill Marshall.
Robert Clark Miller.
James Edmondson Monk, B.Sc.
Fazal Goolamhoosein Mooraj.
Nai Morar.
Edward Harold Morris.
Clement Tudway Mullings.
Alistair Roderick Murray.
Hugh Gerald Nangle.
Polisetti Ranganayakulu Nayadu, B.C.E.
Douglas Claud Newmarch.
Edward Nicholson.
William Morton Park.
David Flower Parker.
John Parkinson.
William Manley Phillpotts.
Thomas Newbold Piddocke.
Roger Chideock Joseph Radcliffe.
Albert Norman Ramsey.
Alexander Brodribb Randall.
Harold Douglas Rice.
James Peat Firth Lindsay Roger.
Percy Gilbert Scott.
Robert Ellis Shawcross.
Joseph Shorrock.
Lightly Stapleton Simpson.
Arthur Charles Irving Smith.
Frederic Bolton Sonnenschein.
Frederick Southey.
Walter Halsted Cortis Stanford.
Duff Steele.
Horace George Summerford.
David Guilland Taylor, B.Sc.
Albert Ernest Thomas.
Aubrey Ward Thomas.
Charles Frederick Thomas.
Sydney Thow.
Percy Marmaduke Tottenham.
John Pountney Udal.
Alberto Luis Gowland Urtubey, B.A.
Cedric George Vaughan, B.A.
Walter Adolph Vignoles.
Joah Haigh Walker.
Gerald Norman Watney.
Burkewood Welbourn.
Edward Medland White.
Bernard Russell Wills, B.A.
Arthur Russell Windham.
Julian Stanton Wise.
Robert Wylie.
James Alan Ferguson Young.
Mansel Charles Gambier Young.

The Candidates balloted for and duly elected were :—as

Members.

Edward McCarthy Allman.
William Reginald Chester.
Joao Chrockatt de Sá Pereira de Castro.
Guillermo Federico Jorge Dominico.
Arthur Sampson Jameson.
James Edward O'Shaughnessy.
John Stirrat.
Charles McDonnell Stuart.

Associate Members.

William Walter Acton.
John Henry Alexander.
Frederic Warner Allum, Stud. Inst. C.E.
John Reid Anderson, Stud. Inst. C.E.
George Samuel Burt Andrews.
Tom William Baker, B.A.
Charles Francis Ball.
Joseph Wilmot Barlow.
Walter George Barnett.
Samuel Harry Hill Barratt, Stud. Inst. C.E.

Associate Members—continued.

William Thomas Bayley.
Lionel Vaughan Bennett, B.E., Stud. Inst. C.E.
Andrew George Brandram.
Joseph Peter Brazil, Stud. Inst. C.E.
Frederick Thomas Brearley, Stud. Inst. C.E.
John Henry Brierley.
Albert Edward Broad.
James Buchan, Stud. Inst. C.E.
Robert Bush, B.A.
Thomas Copley Calvert, Stud. Inst. C.E.
Humfrey Alleyne Carte, Stud. Inst. C.E.
George Fearnley Carter, Stud. Inst. C.E.
Samuel Christopher Chapman, Stud. Inst. C.E.
William Betham Clark.
Charles Thomas Copley.
Alexander George Cox.
Charles Crighton, Stud. Inst. C.E.
James Alfred Crowther.
Isidro Diaz-Lombardo.
Walter John Fletcher.
Thomas James Moss Flower.
John Charles Forrest.
Alfred Blount Fry.
Arthur Robert Gale, Stud. Inst. C.E.
John Wishart Fairlie Gardner, Stud. Inst. C.E.
Tom Ernest Gatehouse.
Richard Henry Good.
Richard Goodman, Stud. Inst. C.E.
John Gordon.
Harry Denis Griffiths, A.R.S.M., Wh.Sc.
Henry Seymour Guinness.
Leonard George Hall, Stud. Inst. C.E.
Henry Sebastian Hart.
Patrick Campbell Hart, Stud. Inst. C.E.
Isaac Thomas Hawkins.
Douglas Theodore Heap.
Brodie Haldane Henderson.
Gerald Maitland Heriot, Stud. Inst. C.E.
Thomas Hewson, Jun., Stud. Inst. C.E.
Alfred Hill.
Joel Henry Horwood, M.C.E.
Frederick William Howard.
Percy Winstanley Hull, Stud. Inst. C.E.
Horace James Jordan Hummel, Stud. Inst. C.E.
Herbert Alfred Humphrey, Stud. Inst. C.E.
Algernon Edward Johnson.
Navroji Hormasji Katrak, L.C.E.
Christopher Watkins King, Stud. Inst. C.E.
August Charles Koch.
William Samuel Lackland.
Kenneth Smale Laurie, Stud. Inst. C.E.
Richard William Frederick Longfield, B.A.
Frederick Herdman Longhurst, Stud. Inst. C.E.
William Bernard MacCabe.
Charles Stewart Douglas Maclean
Charles Christian Malsch.
William Wright Marriner, Stud. Inst. C.E.
Charles Mayne.
John Ezra Miller.
John Stott Millington, Stud. Inst. C.E.
Charles Siddall Milner.
George Moncur, B.Sc.
George Edwin Morris.
Hugh James Morton, Stud. Inst. C.E.
Oswald Gordon Morton.
Thomas Moulding.
Kiyoichi Murakami.
Arthur Norton, Stud. Inst. C.E.
Richard Newcome Oakley.
James Ignatius O'Donnell.
Kumema Okura.
Leontine Wallace Olive, M.A.
Manoel da Silva Oliveira.
Henry James Orford, Stud. Inst. C.E
Frank Owen.
Francis Parr.
Percy Marriott Payne.
Marshall Petree.
John Phillips.

Associate Members—continued.

William Poole, Jun., Stud. Inst. C.E.
John Pownall, Stud. Inst. C.E.
John Henry Onslow Reid.
Frank Paul Reynolds.
John James Robson.
Christian Martin Crone Rovsing, B.A.
Samuel Thompson Scharschmidt.
Alfred Schwartz, Stud. Inst. C.E.
Robert Humphrey Sears, Jun., Stud. Inst. C.E.
George Harrison Sheffield, Stud. Inst. C.E.
James Sibbald.
Alexander Arthur Dalrymple Smith, B.Sc., Stud. Inst. C.E.
James Gould Smith.
Thomas William Stainthorpe.
William Blackwall Statham, Stud. Inst. C.E.
Holman Fred Stephens, Stud. Inst. C.E.
Ralph Harry Stephenson.
Edward Duncan Stoney, Stud. Inst. C.E.
Herbert Walter Stride, Stud. Inst. C.E.
Sundaraiyar Arumbur Subrahmanyam, Aiyar, *Rai Sahib*, B.A., B.C.E.
Norman Maughan Taylor, Stud. Inst. C.E.
John Thompson, Jun., Stud. Inst. C.E.
Richard Clement Tiplady, Stud. Inst. C.E.
Joseph Fletcher Toomer.
Samuel Towlson.
Nicholas Trestrail.
Arthur Clifford Turley.
James Henry Tyrrell.
James Scargill Wade.
Edward Henry Wallich.
Thomas Lister Walsh.
George Watson, Stud. Inst. C.E.
William Park Weir, Stud. Inst. C.E.
Henry Thomas White, Stud. Inst. C.E.
Francis Langham Wilder.
Daniel Ellis Wilson.
Oliver Ernest Winter.
Francis Wood, Stud. Inst. C.E.
Arthur Worthington, Stud. Inst. C.E.
Thomas Wylde.
Robert Owen Wynne-Roberts.

Associates.

Charles Barry.
Augusto Duprat.
Joseph Henry Judd.
Charles Hay Walker.

The discussion upon the Paper on "The Machinery of War-Ships," by Mr. A. J. Durston, was continued and concluded.

11 December, 1894.

SIR ROBERT RAWLINSON, K.C.B., President, in the Chair.

(*Paper No. 2838.*)

"Colliery Surface-Works."

By EDWARD BROWNFIELD WAIN, Assoc. M. Inst. C.E.

ALTHOUGH the details of underground works are necessarily of primary importance in the successful working of coal, the surface-arrangements constitute an important part of colliery establishments. If convenient arrangements are made to facilitate the loading and preparation of the material for market, considerable economy in working may be effected. By careful attention to the details of the plant, it is possible to reduce the expenditure upon labour at the surface to about one-twelfth of the whole labour-cost. The marked increase in the production of coal in the United Kingdom, in face of burdensome legislation, reduced hours of labour and difficulties consequent upon the greater depth at which the mineral is wrought, is largely due to improved mechanical appliances.

The North Staffordshire coal-field, to which this Paper chiefly refers, furnishes a good example of the development of mining-operations. Although there may be mining-districts in which there are more varied objects of interest and collieries better equipped with modern machinery, it is hardly possible to point to any mines that have been worked for a considerable period in which such great improvements have been made of late years. Speaking of this coal-field, Professor Hull observed, "In the two years extending through 1857–9 the production nearly doubled itself; and since that time it has increased by about three-fourths, while the number of collieries has not proportionately increased; showing the larger scale upon which the mines are now being worked."[1] In 1878, the field yielded 4,098,338 tons of coal and

[1] "The Coal-Fields of Great Britain." 4th edition. London, 1881, p. 189.

ironstone. The statistics for 1893 show that the annual output of coal and ironstone has been increased to 5,755,357 tons, an increase of upwards of 40 per cent. in twelve years. There is hardly a colliery in the district the plant of which has not been considerably improved during the past twenty years; and there are numerous instances of the development of extensive plants from small beginnings, such as mark the history of coal-mining in many of the older coal-fields, but particularly in the one referred to.

The considerable angle at which the strata occur results in the outcrop of numerous seams of coal and ironstone in close proximity, thirty-four valuable seams coming to the surface within a space of 2½ miles. These conditions were favourable to shallow workings with adits and small pits, in which horse-gins and windlasses were used, and twenty years ago a large portion of the mineral raised came from such workings. As the upper breadths were worked out, it became necessary to put down suitable winding-machinery, and within the last fifteen or sixteen years more important plants have been introduced. A proof of the efficiency of the methods now generally adopted is afforded by the fact that, though the natural difficulties of working are greater than in most other coal-fields where the seams lie at moderate inclinations, yet the average weight of mineral wrought per workman in the North Staffordshire district is higher than the average for the United Kingdom, the relative figures being 302 tons in the former case and 257 tons in the latter.

Under such circumstances it has been difficult to apply general principles in laying out colliery surface-works. As necessity has arisen, extensions and additions have been made, and the work may be described as one of evolution rather than of design. Comparisons made between such works and those laid out recently on modern principles for a definite output, will probably indicate much waste and inconvenience resulting from spasmodic and desultory extensions.

In Fig. 1, Plate 4, is shown the general arrangement of the Whitfield colliery, which thirty years ago had an output of little over 200 tons per day and is now raising ten times that quantity. The dark shaded buildings in the Fig. show the nucleus around which the present works have grown. It may be somewhat invidious to compare this with newer plants erected during the last few years; still, as regards convenience and general arrangements, there are many points worthy of notice, to which the Author proposes to direct attention later. In designing colliery plant, it is generally necessary to allow a large margin of strength

to meet the shocks and stresses peculiar to this class of work, and it is not as a rule advisable to introduce mechanical appliances of an intricate character.

General Arrangements.

It is of the highest importance that the works should be concentrated as far as possible, so as to permit efficient supervision and to reduce the staff of mechanics and general labourers. A good example of this is exhibited by the colliery mentioned, where in 1876 six small and scattered plants were at work on the property, and were raising less than one-half of the material now being obtained from two shafts. As the plant at each shaft requires its staff of engine-men, stokers, pit-banksmen and foremen, it is evident that great economy is effected by reducing the number of such establishments. In the case mentioned, the reduction in surface-charges effected by concentration has amounted to 4·67*d.* per ton.

Railways.—As it is usual to screen the coal direct into the railway-wagons to the various sizes required for sale, the greatest care is required in laying out the sidings so that work may proceed without hindrance; and, where practicable, the railways should be so arranged as to allow a gentle descent for the wagons to and from the screens. Where the nature of the ground will not admit of this, endless ropes working between the rails are of great service. In no case should dead-end sidings be used if a regular output is to be maintained, as the time lost in shunting wagons will cause serious hindrance to the coal-winding. It is also desirable that each quality and size of coal should be delivered on a separate road so as to allow of continuous loading. A good arrangement is shown in Fig. 1, Plate 4, where the sidings as laid out at the Whitfield Colliery are indicated. Empty wagons are hauled by locomotive power to the highest point and are left in sidings arranged on the "gridiron" principle. From this point they are run down as required into the various screen sidings, a separate line being provided for each of the ten classes of coal. When loaded, the trucks are lowered down to the weighing-machine, which is situated at the place to which the lines converge. After being weighed, the trucks are marshalled in sidings below, ready for transit outwards. It will be seen that by this arrangement all locomotive work through the screens is avoided, and that from the time empty wagons are placed in the sidings above the pits until they are taken away loaded by the branch line, no loco-

motive-power is required. It is found that an average gradient of 1 in 30 is suitable for the empty sidings. This may appear to be steeper than is actually necessary, but allowance has to be made for accumulations of coal-dust under the screens and of snow on the rails in winter. In the sidings below the screens, it is found that the loaded wagons run well on a gradient of 1 in 76.

The cost of shunting is by this means reduced to a minimum, that of dealing with 1,800 tons in eight hours being—

	s.	*d.*
Two shunters (youths) lowering empty wagons to screens at 3*s.*	6	0
Two shunters taking loaded traffic over machine, one at 4*s.* and one at 3*s.* 4*d.*	7	4
Total	13	4

equivalent to 0·09*d.* per ton or about 0·5*d.* per ton per mile.

The considerable length of sidings made available is found to be very convenient, allowing an ample supply of empty wagons to be in position above the screens and providing good standing-room for loaded traffic below, so that any temporary hindrance in working the traffic over the main line does not interfere with the working of the pits. Accommodation for upwards of 100 wagons is provided in the storage roads above the screen-sidings. The through lines used by the locomotives to take the wagons into the storage sidings are laid with single-headed steel rails weighing 84 lbs. per yard; the screen sidings are laid with flat-bottomed rails which weigh 50 lbs. per yard.

Workshops.—Well-fitted workshops are necessary for the purpose of maintaining the mechanical appliances used at collieries. The Author is of opinion, however, that it is not advisable to undertake new work of importance in colliery workshops, but to use them simply for the purpose of making such repairs as may be necessary. In districts where there are good engineering works near to the collieries, even a portion of the last-mentioned work may with advantage be sent out; but where there are not facilities for doing it near at hand, it is of the highest importance that all necessary tools and machinery for repairs should be provided at the colliery. A good smithy, with a small steam-hammer, lathe and drilling-machine, should form part of the equipment, and a carpenters' shop and a saw-mill are also required. Where practicable, the workshops should be built on a level with the pit-bank, and light tramways of the same gauge as that of the underground roads should be provided to facilitate the transport of material from the shops to the pit-shaft. A small pick-smithy

for sharpening the miners' tools, and a shop for light repairs to pit-wagons, placed as near to the shaft as possible, will be found useful in most cases. Fig. 2, Plate 4, shows the arrangement of the carefully planned workshops erected for the Whitfield colliery, where 2,000 tons of coal are raised daily. The shops include a saw-mill, with an engine driving a circular saw, a carpenters' shop with a joiners' and pattern-makers' shop attached, a fitting shop with two lathes, planing-, shaping-, boring- and screwing-machines, and a smithy with four fires and one 3-cwt. steam-hammer.

The lamp-room, in which the safety-lamps are cleaned and trimmed, is also included in the same range of buildings; that shown in the Fig. being designed to accommodate about 1,600 lamps. Owing to the greasy nature of the work, it is desirable that the fittings should be made of iron throughout, so as to render the building as nearly as possible fire-proof. The lamps may be stored on narrow shelves fixed on the walls near to the places where they have to be given out, each lamp being numbered and the shelves bearing corresponding numbers. The numbering is done so that each workman may have the same lamp from day to day; the number and the user's name are registered in order to assist identification in the event of damage resulting from the careless handling of any lamp. It is important that the lamp-room should be large enough to allow space for the lamp-men to move about with ease when giving out the lamps. It is not unusual for upwards of 1,000 lamps to be passed out in twenty-five minutes, and to prevent delay a sufficient number of issuing-places should be provided. A lamp-cleaning-machine with rotary brushes, of which there are several types in the market, is of great service. In the lamp-room arranged as shown, three men and one boy can give out 900 lamps in twenty minutes. The actual number of lamps in use is 1,500, and the cost is as follows:—

	£.	s.	d.	Per lamp per week. d.
Labour for cleaning, trimming and repairs, five boys and two men	5	16	6	0·93
Material—oil,[1] 72 gallons of colza at 2s. 1½d. 36 gallons of petroleum at 5d.	8	8	0	1·34
Sundry stores	0	11	6	0·09
Cost of one lamp per week				2·36

[1] Two gallons of oil, 2 parts of pure colza to 1 part of petroleum, fill 166 lamps for ten hours' burning.

Pit-Bank Arrangements.

As the weight of coal carried in pit-wagons rarely exceeds 10 cwt. in English collieries, it is necessary, where large quantities have to be raised, to make such arrangements on the pit-bank as will allow the material to be easily handled. To land an output of 1,000 tons per day will require not less than 2,000 wagons to be brought to the pit-bank in eight hours; and as each one of these has to be taken from the cage, weighed, conveyed to the screen, emptied and returned to the pit, it follows that the arrangements must be such as will allow a continuous train of wagons to be passed. The size of the wagons, and therefore the weight of the coal carried, is generally limited by the height of the seam worked, but 10 cwt. may be taken as their average load in English collieries. In the South Wales coal-field wagons to carry a load of 20 cwt. are admissible on account of the exceptional thickness of the seams there worked. As will be seen by the Table in the Appendix the weight of the coal forms a small portion of the total load raised, so that any reasonable increase in it would not in most cases overtax the engine-power. In seams between 3 feet and 5 feet thick, wagons carrying about 8 cwt., and measuring 4 feet long, 3 feet wide, and 2 feet deep in the body, are generally used, and are as large as can be conveniently handled and loaded in the workings. In the thicker seams, up to 7 feet, larger wagons are used, on an average about 4 feet long, 3 feet wide, and 2 feet 6 inches deep, and carrying about 10 cwt. The weight of such a wagon if strongly built, to resist the rough handling it meets with underground, is not less than 5 cwt., giving a gross weight of 15 cwt.

The wagons are generally built of larch or elm boards 1¼ inch to 1½ inch thick, but advantage would result if thin steel plates were more generally used in substitution for the wooden sides and bottom. A pit-wagon of the same outside dimensions as those last mentioned, but with a steel plate bottom $\frac{3}{16}$ inch thick instead of 1½ inch larch boards, and plate sides ⅛ inch thick instead of 1¼ inch boards, weighs 6 cwt., and has a capacity of 12 cwt. This would give an increase in the quantity raised of 200 tons per day where 2,000 wagons are used. The chief objection to the use of steel or iron in the construction of pit-wagons has been the greater cost of repairs when wagons meet with such accidents as are frequent in underground workings. The Author has found, however, that steel wagons which are put together with short screw pins instead of rivets are repaired with no greater difficulty

than wooden wagons; and, further, the damaged plates of steel wagons may be straightened and used again, whilst the broken boards of wooden wagons are valueless.

With the use of screw pins in the construction of the steel wagons, it is found better to put a thin liner of hard wood between the plates at the joints, so as to allow a firmer grip to be obtained than when the two hard steel faces are screwed together.

The gross weight should not be increased beyond 18 to 20 cwt., for if this weight is exceeded much delay to the work results if a wagon leaves the rails, especially in inclined seams. Owing to the shifting nature of the ground, it is difficult to maintain the underground tramways in a thoroughly efficient state, and therefore the question of replacing the wagons on the rails is of considerable importance. It is also undesirable in seams producing much small coal to have so large a load as to unduly encumber the screens; for in such cases there is more difficulty in separating the small from the lump coal than when smaller loads are used. With the improved haulage arrangements by means of endless ropes now in general use, the quantity of coal which can be conveyed along the underground passages is largely increased; and in cases where it is found that the output is limited by the quantity raised in the shaft, it will be better to increase that quantity by employing additional winding-power and a greater number of decks on the cage, or even by duplicating the shafts and winding machinery, than to use wagons which are too heavy to be handled conveniently.

The coal is usually brought to the pit-bank in cages with two or more decks, carrying two wagons end-to-end on each deck. If in changing loaded for empty wagons the cage has to be stopped at the pit-bank level to deal with the first deck, and be subsequently lifted for the operation to be performed with the lower deck or decks, much time is occupied; and in order to avoid such delay it is desirable to make arrangements for changing the decks simultaneously.

Where more than two decks have to be changed, the hydraulic arrangement, Fig. 3, Plate 4, invented by Mr. George Fowler, and erected by him at the Cinderhill and Hucknall Collieries, Nottinghamshire, and elsewhere, is a most valuable contrivance. It consists of cages moved by hydraulic power, with the same number of decks as the pit-cages, fixed on each side of the pit. One of these is filled with empty trams and is raised into position. The other cage, empty, is also raised to the same level. As soon as the pit-cage reaches the surface, hydraulic-pressure is applied to

pistons which push the empties into the main cage, and at the same time force the loads on to the cage standing ready to receive them on the opposite side, when the main cage is again ready to be lowered down the shaft. While the cage is running in the shaft, the hydraulic cages are lowered, deck by deck, to the pit-bank level, the loaded trucks are removed from the one and a fresh supply of empties is placed in the other, and they are again raised into position to await the return of the main cage. By this means, the time occupied in changing the wagons on any number of pit-cage decks is the same as that required for one deck. Where, however, there are only two decks to be dealt with, the simplest plan is to fix a platform above the pit-bank level, so as to allow both decks to be changed at the same time. The loaded wagons on the upper deck are run down to a balance-cage connected with a similar cage behind the pit, by which two empties are raised. This arrangement has been introduced at several collieries, one of the best examples of it being that at the Harton Colliery, Durham.[1] Figs. 4 and 5 show an arrangement of this kind constructed by the Author a few years ago at a pit where it is required to deal with 1,000 tons, or 2,000 wagons, daily. The balance-cages being fixed out of the sight of the engine-man, allow him a clear view of the pit-top. It may be seen that the loaded wagons gravitate from the pit-cage to the balance-cage, which is connected with the cage for the empties by wire-rope $\frac{3}{4}$ inch in diameter. The difference in height required to allow fall for the empty wagons to, and the loads from, the cage, renders it necessary to use pulleys of different diameters; and the empty cage being on the larger pulley, power is gained to raise the other cage into position again without balance-weights. The actual saving in winding by this arrangement in a pit 420 yards deep is as follows:—

——	When changing Decks separately.	With the Double Platform.
Time of winding	40 seconds	40 seconds
Changing wagons	25 "	10 "
Totals . . .	65 "	50 "
Maximum runs per day of eight hours . .	443	576
" weight per day (2 tons per run) .	886 tons	1,152 tons

[1] Trans. Federated Inst. of Mining Engineers, vol. i. Plate VI., illustrating Messrs. Forster and Ayton's Paper "On Mechanical Coal-Cleaning."

This shows an increase of 266 tons per day, or 30·7 per cent. on the smaller weight.

The Mines' Regulation Act provides that "where the amount of wages of any person depends on the amount of mineral gotten" it "shall be truly weighed at a place as near to the pit-mouth as is reasonably practicable." As the large majority of miners are paid by weight, it is necessary to weigh each loaded wagon before it is emptied at the screens, and it is usual to place a weighing-machine near to the pit-shaft. This machine should, however, be placed at such a distance from the shaft as to allow standing-room for a full cage-load of wagons between the machine-plate and the cage. Where a large number of wagons has to be rapidly weighed, a self-recording machine should be used. There are several kinds of scales specially adapted for this class of work; the Author has used two Pooley water-balance machines for several years, and has found them to be quick in action and reliable in every way. Between the weighing-machine and the screens it is advisable to allow some little siding-room for the loads, so that any temporary stoppage of the screens, such as that required for changing railway-trucks, will not stop the work of the pit. Where this is done, some means of hauling the wagons to the screen should be provided. Fig. 5 shows an arrangement of creeper-chains and gravity-roads to and from the screens, which is calculated to deal with 1,000 tons daily in eight hours. As the loads leave the weighing-machines they are pushed on to a creeper-chain which catches the axles and hauls them up a short incline rising 1 in 10; after reaching the summit they run clear of the chain down an easy incline of 1 in 40 to the tippler, where the coal is emptied into the screen. The tippler, which will be referred to later, is so arranged that the loaded wagons push out those last emptied. When the empties leave the tippler, they are twisted on the turn-plates to a second creeper-chain which hauls them up an incline of 1 in 4, from which they run back to the pit ready for filling the pit-cages again. The creeper-chains run at about 60 feet a minute, and the whole time occupied in weighing, conveying to the tippler, emptying and returning the empty wagon back to the pit, a total distance of about 300 feet, is two minutes.

The cost of labour for banking 1,000 tons per day by this arrangement is as follows:—

	£.	s.	d.
Two men pushing empty wagons into the cage	0	8	6
Two men taking loads out and weighing	0	8	0
Two men at the front of the tippler	0	6	8
One man behind the tippler, twisting empty wagons .	0	4	0
One boy removing and sorting tallies from wagons . .	0	1	6
One man at the balance-cage	0	3	8
One boy filling the empty balance-cage	0	1	6
Total . . .	1	13	10[1]

Cost per ton, 0·4*d.*

Controllers.—For regulating the supply of wagons, Woodworth Controllers, Fig. 6, are found to be of great service. This apparatus is designed to control the delivery of wagons on inclined planes without an attendant to block or release them. It can be opened from any distance by the person requiring the wagons, and all the movements are automatic. To open the controller, the sliding bolt E is moved by a lever on the shaft G. This moves the axle-catch A to such a position that the wagon-axle B runs freely over. The star-wheel C is propelled by the following axles until the cam-point D comes in contact with the heel of the sliding bolt at E^1, and draws it back so that the catch A falls and stops the delivery of wagons until it is again released. The spring F presses against square projections on the star-wheel and regulates its revolution. The controllers may be arranged, by varying the number of teeth in the star-wheel, to pass one, two or three wagons; the pattern illustrated has four teeth in the star-wheel, and is designed to pass two wagons.

Tipplers.—In order to empty the coal into the screens, some device by which wagons may be easily turned over is required. Figs. 7 and 8 show an ordinary back tippler which is largely used for the purpose. The loaded wagon is run into the tippler, which is set in line with the tramway and is carried on two central journals. Stop-forks are fixed on the frame, which catch the axle of the wagon and hold it so that the centre of the load is a little behind the centre of the tippler. When the catches are drawn back, the heavier end sinks and causes a partial revolution of the frame; the wagon, held firmly by the forks over the axle, is turned almost upside down, and is held in that position until the coal has fallen out. When the brake is released, the heavy portion of the wagon, *i.e.*, the wheels and axles, tilt the frame of

[1] These figures show the wages paid prior to August, 1894, which have since been reduced 7½ per cent.

the tippler back to its original position, the catch is pushed in and the empty wagon is removed. The tippler-frame may be either circular as shown in the Fig., or a square cage as in the North of England, or even a flat plate with rails and journals attached as in some of the Lancashire collieries. The only detail common to the various patterns is the central bearing on which the frame is carried; this is so fixed that when a loaded wagon is placed in the tippler, the weight of coal above the centre will cause it to revolve to such a point that when emptied the weight of the lower portion will cause its return. The objections to this tippler are—that it is difficult to regulate the speed at which it is revolved, and that the coal has to fall a considerable distance to the screen-plates below, causing in the case of tender coals serious breakage and an increased amount of slack.

Rigg Tippler.—In the Rigg tippler, Figs. 9 and 10, the fall of coal from the wagon to the screen is checked by a swinging door, and by a shoot which forms part of the frame of the tippler.

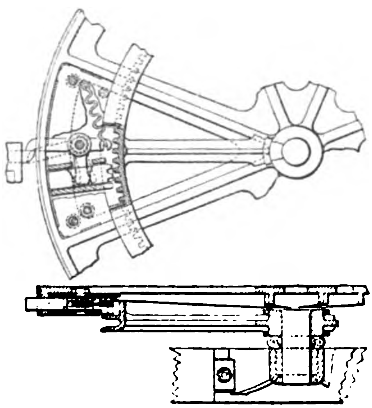
Side Tipplers.—The most suitable plan is, in the Author's opinion, an arrangement by which the coal may be emptied over the side instead of over the end of the wagon. Where this is done, it is somewhat more difficult to arrange the balance of the load. Side tipplers are generally heavy to work by hand, and are consequently not so quick in action as ordinary end tipplers. Where power is available, the difficulty may easily be overcome by fixing small friction-rollers which can be pressed against the circumference of the tippler frame. Figs. 11 and 12 show a side tippler with friction-gear designed by the Author, by means of which wagons containing a load of 10 cwt. may be emptied at the rate of six per minute. This tippler is carried on disk-wheels so as to allow a clear road through for the wagons when empty.

Heath-Woodworth Tippler.—This is an end tippler arranged to be driven by power, which, after starting, is automatic in action. A cog-wheel worked by a rope or chain from the screen-engine is placed on the centre axle, but working free. A short rack with teeth of the same pitch as the cog-wheel, and fixed to the side of the tippler frame, is thrown into gear by a lever, and the tippler is steadily revolved, *Figs. 13.* The rack is thrown out of gear automatically when a complete revolution has been made. By means of a modification of the Woodworth Controller, the wagon is held securely in position without the use of forks as in the ordinary end tippler, and this allows a straight run through for the empty wagons. One man can pass 200 to 300 wagons per hour

through this tippler, and the coals are delivered steadily with a minimum of breakage.

Screens.—Sorting, sizing and preparing the mineral for the market are perhaps the most important of colliery surface-operations, but where the surface-works have been at the outset well planned, there are no special difficulties. The apparatus used is generally very simple, except where one seam contains two or more qualities of coal, or where there are bands of dross or stone which have to be removed, in which case hand-picking belts are required. The subject of screening and picking apparatus would, in itself, afford material for a lengthy Paper, and the Author proposes to give only a short description of some of the types of screen in

Figs. 13.



Scale, 1 inch = 1 foot.

DRIVING-GEAR OF HEATH-WOODWORTH TIPPLER.

general use. In laying out the heapstead it is important that there should be sufficient height between the pit-banks and screen-siding levels. The height will vary considerably according to the type of screen used and the number of sizes to be made. In practice it is found that with fixed bar-screens, not less than 20 feet is required if the coal is to be separated into three sizes, whilst with jigging screens it is possible to do the same work with 16 feet where no picking belts are required.

Fixed Bar-Screens.—Fixed bar-screens, Fig. 14, Plate 4, may be employed with advantage where the quantity to be passed does not exceed 200 to 250 tons per day, and where the seam is fairly strong, and contains only a low percentage of small. The flattest gradient

should not exceed 1 in 3 or thereabouts for the round coal, but it must be steeper for the smaller sizes. Steel bars of taper section are fixed parallel in cast-iron bearers, with distance-pieces to space the bars. As the coal slides down, the smaller particles fall through upon a fixed shoot if two sizes only are to be made, or on a second set of bars of closer mesh if further separation is required. The coal when tipped on such a screen slides down at a high velocity, and in the case of brittle seam a large amount of small is made by breakage on the screen, and further, where the coal to be screened contains much small, the larger pieces carry a good deal of slack with them into the coal-truck. Where the screens are flattened to prevent this, hand-labour has to be employed in raking down, and the cost of screening is greatly increased. Under such conditions it becomes necessary to provide some other means of dealing with the coal, for which purpose there are various types of mechanical screens.

Mechanical Screens.—These may be classed under three heads:—1st, revolving-barrel screens; 2nd, endless-belt screens, such as the Lührig belt and the Greenwell screen; 3rd, jigging screens, these being the kind in most general use.

Revolving Screen.—The revolving screen is the oldest mechanical screen, and consists of a cage of bars usually set longitudinally and carried on a central axle driven by gearing from a small engine. Where several sizes have to be made, there is a series of inner rings carrying bars of varying mesh, the widest mesh being inside. The screen is set with a fairly steep inclination, say, 1 in 5 to 1 in 6, and the coal to be screened is delivered into the centre of it. Such an appliance cannot be used with advantage for large coal owing to the amount of breakage caused by the large pieces being carried up the sides of the cylinder as it revolves and falling down upon the coal below. Where, however, it is required to separate a quantity of slack into several sizes, as is necessary with many coal-washing machines, the revolving screen is best adapted for the purpose; and it is not uncommon, with a machine of this type, to make five sizes from slack which has been previously screened through bars of 1½ inch mesh.

Endless-belt Screens.—The Lührig belt consists of a series of short iron bars coupled together to form an open chain of alternate bars and openings of equal width. This is principally used where it is required to chip bands of dross from the coal. In dressing the coal, a certain quantity of small is made, which falls through the open spaces and is conveyed into the proper

receptacle for slack. The Greenwell screen, Fig. 15, consists of a series of endless chains carried on grooved drums at both ends of the screen, and driven by gearing from a small engine. The chains travel between fixed bars of varying widths and of Λ section. The widest bars are at the end of the screen where the coal is tipped, and the space between them and the moving chains is only sufficient to allow the smallest size to pass. The coal is carried forward to a point where the space is increased by the bars becoming narrower, and the next size is there allowed to pass, and so on. The chief advantage of this screen is that it serves as a picking-belt as well as screening the coal. Another advantage is that very little elevation is required; any number of sizes may be made with a pit-bank only about 12 feet above the rail-level. The speed of the chains is about 45 feet per minute, and the gradient is 1 in 30, or even less. The engine-power is small; an engine with a 9-inch cylinder, working at a pressure of 45 lbs. per square inch, easily drives two screens passing 250 tons per day each. Side-tipplers are a necessity with this screen, in order that the coal may be delivered evenly over the surface.

Jigging Screens.—The most difficult conditions in connection with coal-screening present themselves where it is necessary to deal with a large output from a tender seam of which a great portion is small. In order to reduce to a minimum the cost of handling the coal, it is desirable to treat the whole output at one point, as each screen requires its full staff of men and boys, whether passing a large or a small quantity. Neither of the screens described is capable of doing this at an extensive colliery without being duplicated. Where the work occurs under the conditions mentioned, some form of jigging screen will generally be the most suitable; and it is quite possible to deal with an output of 1,000 tons per day with one screen of this type where the seam is fairly free from shale and where not much hand-picking is required. The ordinary pattern of jigging screen consists of one or more iron trays fitted with screen-bars, or strong iron gauze of suitable mesh. The pans are hung so as to allow free movement, and are driven backwards and forwards by rods connected with cranks or eccentrics. Owing to the exceptionally heavy nature of the work, the wear and tear is considerable, and the apparatus must be strongly constructed. It is, however, desirable to make the body of the screen as light as is consistent with strength, so as to reduce the weight of the moving parts. The screens may be driven either from the end or the side.

The Lyall screen, which is the best type of side-shaken screen, consists of a heavy iron casing with the screen-grids fixed in tiers. It is thoroughly efficient in action, but is most suitable for a strong coal. As the coal passes down over the screen-grids, which are placed at an inclination of about 1 in 4, it is thrown from side to side and the small is thoroughly separated from it. Between 500 tons and 600 tons is the maximum quantity which can be passed daily over one screen of this type. There appears to be too much knocking about, and consequent breakage of the coal, to allow this pattern to be largely used for tender coal. Very strong framing and supports are necessary to resist the side motion. To provide counterbalance, so as to reduce the shock, it is well to work two of these screens from the same line of shafting with cams or cranks set in opposite directions. End-driven jiggers will be generally found most suitable, as the coal may be passed over them with a smoother and more regular motion. The speed at which the screens are driven will depend on the quantity of coal to be passed, the angle of inclination at which the bars or gauze is set, and the throw of the cranks. A short quick movement is generally found most effective, and the Author's experience is that with a throw of 4 inches to 5 inches a speed of about 100 revolutions per minute of the driving-shaft will be sufficient. If the motion is too smooth and even, as would be the case with a greater throw and lower speed, there is danger of the mass of coal passing without being properly separated, as in the case of fixed bar-screens. The same result will follow if the screen is fixed at too high an angle and the coal passes over at too great a velocity. An inclination of 1 in 4 for the moving parts should not be exceeded in any case. Cranks will as a rule be found to be more suitable than eccentric cams, the former giving an intermittent onward movement which effects a better separation than the more regular oscillation given by the latter apparatus. At the same time, it is easier to adjust and take up the wear on the crank-bearing by gib and cotter than it is to adjust the eccentric-straps on the cams.

In constructing the screens, it is advisable to use two pans, set either one over the other or tandem, so that the movements may be counterbalanced. Fig. 16 shows a useful end-driven jigger erected by the Author some years ago. This was designed to separate coal containing about 30 per cent. of small into three sizes, *i.e.*, coal over 2-inch × 4-inch mesh, cobbles through 2-inch × 4-inch and over 2-inch × 1-inch mesh, and slack through 2-inch × 1-inch mesh, and to pass 500 to 600 tons per day of eight hours.

The cost of this jigger was—

	£.	s.	d.	£.	s.	d.
Timber	31	2	4			
Iron for pans, shafting &c.	21	15	4			
Steel wire grids	3	10	0			
				56	7	8
Labour—making and erecting				20	5	0
Total . . .				76	12	8

These figures do not include the cost of the engine, nor is there any allowance for management or establishment charges.

For passing a larger quantity under less favourable circumstances, where the amount of small is equal to almost 40 per cent. of the whole output, and where it is necessary to deal with the coal at the rate of 1,000 tons per day of eight hours, the Wain shaker-screen, Fig. 17, has been designed. In this apparatus, fixed shoots are used to pass the coal to and from the shakers, the pans of which are only about 6 feet square. By this means the weight to be moved is much reduced. A pair of eccentric cams on each side drive double-ended cranks keyed on a shaft which is carried in bearings and is free to vibrate. The upper ends of the pans are coupled to the cranks, the lower ends being carried by hangers. A reciprocating and oscillating movement is secured, which gives a better riddling action to the screen than is obtained in the ordinary jigger and allows the pans to be set at a very low inclination, the upper pan being set at 1 in 14 and the lower at 1 in 6. The power required to drive the screen is small. With this machine 3 tons per minute (equivalent to 1,440 tons per day of eight hours if the screen could be kept continuously at work) are thoroughly screened with a minimum of breakage. Perforated steel plates are used instead of bars or wire grids, and serve for taking the cobbles and slack from the coals—the smooth surface presented by them admitting of a flatter inclination than can be obtained with the usual wire mesh. In the perforated plates the area of screening-surface is reduced. For this reason they are less suitable to the subsequent screening of the fine slack from the cobbles in the lower pan, and wire grids of 2-inch × 1-inch mesh made of wire ¼ inch in diameter are used.

Winding-Appliances.

The head-gear shown in Fig. 4, Plate 4, is of the ordinary type of wooden frame used to carry the pit-top, pulleys &c. In some of the newer plants lattice ironwork or rolled girders are being

employed in place of timber, but without any alteration in the general design of the head-gear.

The height from the pit-bank level to the centre of the pulleys varies considerably, but about 50 feet will generally be found sufficient to allow clearance above the cages and tackling-chains. The winding-engines in general use are horizontal coupled engines with plain slide- or Cornish valves, and with the rope-drum mounted direct on the crank-shaft with two ropes, one ascending as the other descends. Compound or condensing engines are rarely employed in modern winding-gear, as the few seconds in which continuous work has to be done, and the variable load, prevent full advantage being gained from those types of engine. In an Appendix particulars are given of the depth and speed of winding at several collieries having large outputs; and it will be seen from these that an average speed exceeding 30 feet per second is attained in most cases. In the case of Walsall Wood, No. 1 pit, which affords one of the best examples of high-speed winding in the Midlands, the maximum speed is reached in eighteen seconds, the first six revolutions being made in 12¾ seconds, the second six in 6½ seconds, and the third six in 5¾ seconds. The total number of revolutions in the run is 25½, of which only 21 are under steam. The time occupied in making the run of 550 yards is forty-four seconds, which gives an average speed throughout the run of 37½ feet per second, the maximum speed being 60 feet per second, or over 40 miles an hour. The maximum possible output for eight hours' winding, with four wagons on each cage, carrying an average load of 13 cwt. of coal, is in this case 1,385 tons, and actually 1,231 tons have been raised in that time. It will be inferred that under such circumstances all complications in the winding-engines must be avoided. With the higher steam-pressures now used, there should be, however, no difficulty in taking advantage of compound working, provided the high- and low-pressure cylinders are both duplicated.

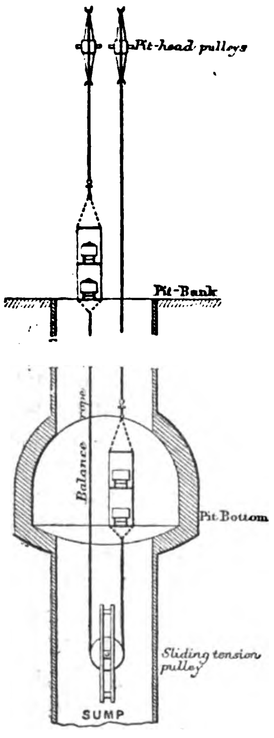
In designing colliery winding-engines, each of the coupled engines is usually made large enough to start the load at any point, as it is possible that one of the engines may be on the dead-centre at the moment of starting; and, with one high- and one low-pressure engine coupled in parallel, there might be some difficulty in adjustment unless there was an arrangement for giving the low-pressure engine some high-pressure steam to start the load if the high-pressure engine was centred—which could only be done by introducing undesirable complications in the valve-gear. If, however, each of the engines were compounded

with high- and low-pressure cylinders fixed tandem, the difficulty might be overcome. Owing to the variable load due to the decreasing weight of the ascending, and the increasing weight of the descending, rope, winding-engines are usually very wasteful in working. The weight of the rope, especially in the case of deep shafts, forms a large portion of the dead load. The weight of the cages and wagons on both ropes is practically the same, and therefore need not be further considered. The weight to be raised is represented by the weight of coal carried in the wagons, and the weight of the rope. In the case of the Sneyd Colliery, No. 2 (Appendix), the weight of the rope is 56 cwt., and that of the coal to be raised 65 cwt. After the moment of starting, the actual unbalanced load, exclusive of friction in guide-rods, &c., is 56 + 65 cwt. = 121 cwt. As the cage is wound up, the weight of the loaded rope is a constantly decreasing, and that of the descending rope an increasing, factor; so that by the time half the run is made the load is

$$\left(\frac{56}{2} + 65\right) - 28 = 65 \text{ cwt.}$$

From this point, the descending weight is increased until at the termination of the run the actual load is 65 – 56 = 9 cwt. These extreme variations of load render it difficult to regulate the consumption of steam in relation to the work done.

Fig. 18.



Plain Balance-Rope.

Various contrivances are introduced to balance the load, but the best and simplest is a plain balance-rope worked with a parallel drum, *Fig. 18.* The balance-rope is attached to the under side of each cage and passes round a pulley in the pit-bottom below the level of the point where the cage is loaded. The Author has been working such a balance-rope for several years in a shaft 240 yards deep where there was no pulley, the rope being simply passed round the timber beams which carry the pit-bottom scaffold. For greater depths it is undesirable to dispense with the pulley, which should be set in slides so that its weight will cause

sufficient tension to keep the balance-rope steady in the shaft. In the Koepe system, there is a simple grooved pulley instead of the usual cylindrical drum, and considerable economy in the first cost of engines and ropes is obtained thereby. The single winding-rope is attached to the cage in the usual manner, passed half round the Koepe drum-ring and back to the other cage. There is always a balance-rope with this arrangement, which is especially suitable for high-speed winding with a light load. For heavy loads it is less suitable, as there is a tendency for the rope to slip a little, which causes inaccuracy in the indicator used to show the position of the cage in the shaft. Many winding-engines are now fitted with drums having a spiral groove, the rope starting on the smallest diameter when the cage is leaving the pit-bottom, and with a well-designed drum of this class a perfect balance may be obtained. The drum is, however, costly, and there is some difficulty in adjusting the rope; on the whole, the most reliable arrangement is a plain parallel drum with a balance-rope under the cages. For balance-ropes, old winding-ropes are found preferable to new ropes, as they exhibit less tendency to twist and curl.

The economy of fuel in colliery-work has received too little attention in the past, the boilers being often supplied with inferior coal or slack which has been considered to be unsaleable. The amount of coal consumed in colliery-work is probably not less than 5 per cent. of the total output of the kingdom; and as slack has now become more valuable, colliery engineers are beginning to give greater attention to the questions of compound working, expansion-gear, condensation, and balanced loads. The engines have been, as a rule, designed to admit steam into the cylinder for almost the whole length of the stroke. Although such an arrangement enables the inertia of the load to be more easily overcome in starting, the back-pressure is considerable in the case of engines running at high speeds, and it is by no means uncommon to obtain from engines working at 80 lbs. per square inch diagrams giving a back-pressure of 10 lbs. per square inch. The general practice is now, however, to cut off steam at about four-fifths of the stroke.

Automatic expansion-gear, either thrown into action by the governors after the engine has reached a given speed, or applied by means of worm-gearing, to gradually increase the cut-off during the run, has been adopted in a few instances with moderate success. The best results are, as a rule, obtained by balancing the load as far as possible, and by adopting expansion-gear which can be

thrown into action by the engineman when the requisite speed has been attained. Condensation, as applied to modern winding-engines, can only be said to have reached the experimental stage, but it is probable that independent surface-condensing apparatus, to maintain a steady vacuum, will be largely used in the future in colliery-works.

Briquette-Works.

The general question of the manufacture of briquette-fuel was dealt with at the Institution in the Session 1893–94.[1] Various methods have been suggested for preparing the small form of non-bituminous coal for coking by mixing tar and other bituminous matter with it, or by adding bituminous coal to the small free-burning coal, but none of these plans have hitherto proved successful. Experiments on this subject are rendered difficult by the lack of reliable information as to the constituent parts of coal necessary for the production of coke.

So far as the Author has been able to follow the subject, chemical analyses of coking and free-burning coals appear to give identical results. It is probable that the difference is of a physical rather than of a chemical nature; and it is often found that a given seam may change from coking to free-burning coal in a short distance. The North Staffordshire coal-field supplies a notable instance of this change, as the lower seams of the series on the west side of the district give good blast-furnace coke, whilst on the east side the same seams give coal which cannot be made into coke by any of the ordinary methods. The change takes place in less than 2 miles; no special reasons are known to account for it.

Although small quantities of coke have been made from non-bituminous coals by the addition of pitch in varying proportions in experimental apparatus, the results have not been such as to warrant extensive application of the methods referred to. Coal tar intimately mixed under steam-pressure gave slightly better results, but in no case was the coke produced of such quality as to be suitable for blast-furnace work, being much inferior to coke from even the commoner qualities of bituminous coal. The various forms of mechanical stokers in the market, with suitable blowers, will consume the smallest coal with good results; but they have

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[1] "The Manufacture of Briquette-Fuel," by W. Colquhoun. Minutes of Proceedings Inst. C.E., vol. cxviii. p. 191.

not hitherto been adopted to such an extent as to lead to any great demand for "smudge" or fine small coal.

In some districts, coal-washing apparatus specially adapted for separating slack into various uniform sizes has been adopted and worked with some success; but it appears doubtful whether any real economy is effected by this method of treating the small, when the interest and depreciation of plant[1] and the cost of washing are considered. In cases where seams contain a high percentage of dirt-partings and dross, some such method of treatment is absolutely necessary to put the slack into a marketable condition. In the course of a recent discussion on coal-washing,[2] Mr. James S. Dixon, of Glasgow, gave some interesting particulars, from which it appeared that slack, separated to five sizes and washed by the Lührig process, yielded, after taking into account the loss in washing, an average price but little in excess of that of the unwashed material.

One other method of treating the small coal, which in the case of anthracitic and free-burning coal has been uniformly successful, is to mix plastic adhesive matter with it and to form it into solid blocks under pressure. Many cementing-substances have been used, but in the Author's opinion the pitch process is the most satisfactory. A small plant of this kind was erected by him in 1892 (Fig. 19, Plate 4). After considering the various types of machine in the market it was decided to adopt that of Stevens, on account of its being simple and automatic in its working and having no parts liable to break or cause trouble in working under ordinary circumstances.

The plant consists of a main bucket-elevator for lifting the slack to the distributor, where it is mixed with roughly-ground pitch which has been raised by a small bucket-elevator to the same point. The distributor is a fluted roller with unequal openings, working in a cast-iron case. It takes certain portions, which may be varied according to circumstances, of pitch and slack from each of the hoppers. The materials are passed from the distributor into a Carr disintegrator, which reduces the larger particles and at the same time intimately mixes the two components. From the disintegrator the mixture is again elevated and is passed into a pug-mill, into which steam at a pressure of 65 lbs. per square inch is blown by three ½-inch nozzles. After the material has been sufficiently heated, it is allowed to fall into

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[1] A washing-plant to deal with 500 tons per day costs £10,000.
[2] Trans. Federated Inst. of Mining Engineers, vol. vii. p. 112.

the lower pan of the machine where revolving arms carry it into the mould. The pressure is applied by a vertical steam-cylinder, the piston-rod of which is connected with a lever that, when raised, acts on the press-hammer and so forces the die upwards and compresses the plastic mass against a fixed plate above. The die-table, with eight dies, is revolved by a rack-and-pawl arrangement worked by a crank on the pug-mill shaft, and steam is admitted by an eccentric on the same shaft. As the table revolves, the finished block is raised by the die which runs up an inclined slide to the point of delivery, where an arm, also worked by the pug-mill shaft, strikes the block and pushes it clear of the table. As the die-table continues to revolve, the die is drawn down by an inclined slide until it again reaches the filling-point. All the moving parts being actuated from the same shaft, there is little possibility of a break-down. The rack-and-pawl arrangement by which the die-table is revolved allows an interval of rest in each revolution, and during that period the pressure is applied. The blocks thus made are sufficiently firm to be loaded direct into railway wagons for despatch. Particulars of the cost[1] of working such a plant have been already given by the Author.

Briquette-making appears to be the most profitable method of dealing with the slack of free-burning coals, more particularly when the seam is so free from dirt partings that the material does not need to be washed before passing through the process of its manufacture into block fuel.

The Paper is accompanied by twelve tracings from which Plate 4 and the *Figs.* in the text have been prepared.

[1] Minutes of Proceedings Inst. C.E., vol. cxviii. p. 248.

[APPENDIX.

APPENDIX.

Name of Colliery and Number of Pit.	Depth from Surface.	Load.					Engine.						Time of Winding.	Average Speed of Winding.	Time of Changing Decks.	Maximum possible Output per Day of Eight Hours.	Remarks.
		No. of Wagons on Cage.	Weight of Rope.	Weight of Cages, Wagons and Chains	Effective Load, i.e., Weight of Coal per Run.	Dead Load at Moment of Starting.	Description.	Diameter of Cylinder.	Stroke.		Steam-Pressure.	Type and Diameter of Drum.					
	Yards.		Cwt.	Cwt.	Cwt.	Cwt.		Ins.	Ft.	Ins.	Lbs. per sq. in.		Sec.	Feet per Second.		Tons.	
Sneyd, No. 1	375	2	18	25	24	67	Horizontal coupled	16	4	0	60	Koepe, 10 feet	35	32·1	10	768	Single-deck cage; balance-rope.
„ „ 2	620	6	56	76	65	197	Ditto	36	6	0	90	Slightly taper, 21 ft. 6 in.	55	33·9	25	1,170	Three-deck cage; decks changed separately; no balance.
Wallsall Wood, No. 1	550	4	30	60	52	142	Ditto	42	6	0	65	Slightly taper, 20 feet average diameter	44	37·5	10	1,385	Double-deck cage; both decks changed simultaneously; double platform; no balance.
Ditto „ 2	550	2	30	32	26	88	Ditto	21	4	6	65	Koepe, 20 feet	35	47·1	10	832	Single-deck cage; balance-rope.
Whitfield, No. 1	240	4	19	63	30	112	Ditto	24	4	0	65	Parallel, 12 feet	27	26·4	23	864	Double-deck cage; cages changed separately; balance-rope.
Ditto, No. 2	420	4	29	65	40	134	Vertical coupled	36	5	0	65	Parallel, 20 feet	40	31·5	10	1,152	Double-deck cage; cages changed simultaneously; no balance-rope.
Denaby Main	450	6	46	72	60	178	Horizontal	40	6	0	70	Parallel, 24 feet	50	27·0	10	1,440	Three-deck cages; decks changed simultaneously by a Fowler hydraulic banking-gear.

Discussion.

Sir Robert Rawlinson. Sir R. RAWLINSON, President, in proposing a vote of thanks to the Author, said that the question of economy in getting and dealing with coal was of the greatest importance. The margin of profit, as he knew from experience, between the production of coal and its sale was very small. In a large concern with which he had been connected for many years, with an occasional out-turn of 20,000 tons per week, the proprietors had derived small benefit, nearly everything having gone in working expenses. The question of working costs was therefore worthy of careful consideration. It was no light thing to turn out coals at the speed with which the machinery described in the Paper was worked, as the slightest fault in any portion of the machinery might result in a serious accident.

Mr. Bainbridge. Mr. EMERSON BAINBRIDGE thought that the President had touched the right point in his remarks as to the value of the Paper in view of the smallness of the average margin of profit in the coal mines of the country. Seeing that the cost of labour in working coal amounted to between 60 and 65 per cent. of the whole expenditure, if machinery could be applied to reduce that charge, the entire cost of working would be largely diminished. It might be considered out of place to refer to the labour question as bearing on the general cost of producing coal and iron in this country; but it was well known that there were now difficulties which did not exist twenty years ago. The manner in which the workmen often maintained the cost of labour beyond what a mine was able to pay, was too well known to require comment. It was therefore all the more important that engineers should seek the best means of economising labour. The mines described in the Paper were in a part of the country where special difficulties had existed, and it was interesting to know that the owners possessed two necessary qualifications for laying out the plant—intelligence in choosing the right kind of plant, and the capital required to obtain it. As to the latter, most proprietors experienced at the present time a deficiency, and were obliged to proceed on the old lines. Most of the appliances described were known to him. With regard to Fig. 6, Plate 4, it was important to be able to have an apparatus which worked automatically. In his experience most automatic

things very soon ceased to be automatic; but the Paper stated that the appliance described had been tried and had worked successfully. He had sent one of his colliery managers to see it, and had learned that it worked well. In surface operations nothing was so important as keeping the coal as large as possible and preventing breakage. To those familiar with coal-mining, the appliances shown in Figs. 7, 8, 9, 10 and 11 would be familiar. It would appear from the plans that the gradual turning over of the coal would cause a very small amount of breakage; but he was sorry to say that the contrary was the fact. The mere turning over of the coal caused an increase of about 6 per cent. in the quantity of small coal, and some mode of reducing the breakage had to be found out. It was not so much due to the fault of the turning of the wagon as to the difficulty of getting the men to do it with the necessary deliberation. The apparatus shown by *Fig. 13* being automatic, could, he imagined, be so arranged that the man could place the wagon, and it would be so regulated that the coal would turn out at a speed which would cause the least amount of breakage. That was a consummation to be wished for in the screening of coal, and it was interesting to know that the Author had it in operation. In all such appliances three things were to be sought: the saving of labour, of breaking the coal, and of the wear and tear of the machinery. Fig. 2 appeared to present two suggestive points for a colliery—a large smithy and a large fitting-shop. Those two premises were used chiefly for repairs. After operations had been carried on a few years nothing was so striking as the immense quantity of repairs required, rendering buildings of that sort most necessary, and it was an important thing to arrive at such a degree of perfection in the machinery and plant as to bring down the wear and tear to the lowest possible quantity. It had often occurred to him that no more useful Paper could be read, as far as mining was concerned, than a Paper on the biography of a scrap heap, explaining how it happened that things became scrap, and how the wear and tear took place. It would be an extraordinary story. During the last day or two a case had come within his experience. In Fig. 4 there was an appliance called a detaching-hook frame—an apparatus for preventing the cage from striking the pulley wheels if the engine-man had the misfortune to overwind it. One of those detaching-hooks had broken, where the apparatus was made to stand a weight of about 60 tons, and with a weight of only 15 tons the hook split in two and the cage went to the bottom of the shaft. It there became scrap-iron, so much so that it could hardly be found. One of the things to be learned

Mr. Bainbridge.

Mr. Bainbridge. was what to do with a thing four times as strong as necessary, which after all broke and caused an accident that might lead to the death of many men. Happily, the hook broke when coal was on and not when men were on; but very great precautions were needed. There were many points of great interest in the Paper; but, as time was limited, he would mention one or two points only to which the Author had not referred. Fig. 4 showed a mode of banking with two decks. Mr. Bainbridge had the same thing working with three decks, thus making it more economical. Again, instead of having three decks emptied on three different levels, in one case he emptied both together on two levels; and at a distance of 360 yards 1850 tons could be raised in eight and a half hours. Another point was with reference to the application of mechanical greasing, viz., the lubrication of the wagons. He had an apparatus in use by which the lubricant was used only once in each month, and the wagons ran without any further application of it. Another important question was the economy of fuel in boilers working on the surface. In the case mentioned in the Paper the consumption was said to be about 5 per cent. In a well-regulated colliery it was brought down to 2½ per cent. The great point was to find the best form of mechanical stoker which would burn coal that was nearly all rubbish. It was very important to be able to burn coal which could not be sold to a customer. It was also important to be able to heat the water before it was put into the boiler by the ordinary feed-water apparatus; but that was a luxury that few proprietors could indulge in. The Author had not referred to the great saving in the wear and tear of the colliery-cage by having small springs on the bottom of the shaft on which the cage fell. He had perhaps applied them, but they were not mentioned. The result was peculiar, and it affected the wear and tear of the cage and of the rivets. It also formed a cushion which, when the cage started from the bottom, enabled the engine to have a rather less load; it therefore gave a relief in winding even when it was balanced as shown in *Fig. 18*. He thought the Author was wrong in regard to the Koepe system, where one rope went over the wheel, and there was only half a turn to do all the winding. He believed there were only two applications of that method in England, and it was a mistake to suppose that the wear and tear of the ropes was reduced by it; indeed, he thought it was increased. The best proof of that was that the Author admitted that the rope slipped; if so, it must have increased the wear considerably. Again, if the rope was worn, the groove was also worn; and he believed that wherever the

system was used the grooves had to be frequently renewed. Another point (a small one) was that oil was used in the colliery. The Author might not be aware of the adoption of a method of lighting all the lamps by electricity by using spirit, which permitted the whole of the lights to be re-lighted without opening the lamps at the bottom of the pit. No reference had been made to cutting coal by machinery. It was very important, when working thinner seams, to ascertain the best mode of cutting by machinery. When he was last at the Institution the question was discussed, and he hoped that other Papers would be written upon it. Mr. Bainbridge.

Mr. T. FORSTER BROWN concurred in the observations of the President and Mr. Bainbridge in complimenting the Author not only on his success at the Whitfield Colliery but on the manner in which he had brought before the Institution the results of his improvements. He was disposed to agree generally with the Author's views; but there were some features in the Paper that he thought were open to discussion. That was especially the case with regard to the opening statement as to "the marked increase in the production of coal in the United Kingdom, in face of burdensome legislation, reduced hours of labour," &c. The inference was that mechanical improvements had kept pace with the increased cost of labour. His experience was that the cost of labour was increasing at a greater rate than improvements in mechanical appliances. There was, therefore, all the greater need for directing attention to improvements in machinery in every direction, especially in connection with surface operations in coal-mining. Seeing that between £5,000,000 and £7,000,000 were expended every year in labour alone on the surface of coal mines, there was abundant reason and sufficient margin for considerable economy. Many of the directions in which economy might be and had been obtained had been fairly pointed out by the Author. One point was that the winding arrangements should be as perfect as possible. In one respect he hardly agreed with the Author. He thought that compound condensing winding-engines undoubtedly tended to economy. In his own experience, a compound winding-engine had been working for two years most successfully without any of the difficulties suggested by the Author of being compelled to apply high-pressure steam to the low-pressure cylinder. Then there were the various surface arrangements, including many mechanical appliances used for underground operations, such as electrical plant and compressed-air engines, all bearing upon economical methods. The following were particulars of an Mr. Brown.

Mr. Brown. instalment of compressed-air plant at the Tymawr Pits of the Great Western Colliery Company, South Wales, perhaps the largest in the coal-mining world, which might be of interest.

The installation consisted of two pairs of air-compressing engines, each pair having a high- and low-pressure steam-cylinder and one air-cylinder placed tandem upon each of two bed-plates. There were therefore in all four high-pressure steam-cylinders, four low-pressure steam-cylinders, and four air-cylinders. The high-pressure steam-cylinders were 22 inches in diameter, the low-pressure 40 inches, and the air-compressing cylinders 34 inches, and the engines had a stroke of 5 feet. Each high-pressure steam-cylinder was provided with expansion-valves on the back of the main slide-valves, variable by hand whilst the engines were at work. The air-cylinders were of the Walker type, provided with the usual water-cisterns. Each pair of engines was provided with a fly-wheel weighing 20 tons. The compressed air passed from the air-cylinders into four steel receivers placed longitudinally outside the engine-house walls. The condensing-plant was of the independent type, and consisted of a pair of steam-engines having cylinders 10 inches in diameter, and double-acting air-pumps, one behind each steam-cylinder, which was 20 inches in diameter, the stroke being 3 feet. There were two distinct engines, each having its own crank-shaft, bearings and fly-wheel, the shafts being connected together by means of a coupling. The condenser was placed between the two air-pumps, and was common to both. The pipes and valves connecting the four low-pressure steam-cylinders with the condenser were so arranged that either one pair or the other could be shut off at will; and in addition, as at certain seasons of the year the water-supply for condensing purposes was limited, the condenser could be entirely shut off, the exhaust then passing direct from these cylinders into the atmosphere. The steam-cylinders of the independent condensing-engine were also connected with the condenser. Steam was supplied from Lancashire boilers at a pressure of 150 lbs. per square inch. The compressed air could be delivered at a pressure of 70 lbs. per square inch. With a piston-speed of about 400 feet per minute there would be in the four air-compressing cylinders about 1,500 I.HP. when working at an air-pressure of 70 lbs. per square inch. A still higher duty than this could be obtained from the compressors if desired. The air-compressing engines for an adjoining colliery (now under construction) were in many

respects similar to those described. The steam-engines were of Mr. Brown.
the "Twin" compound type, having high-pressure steam-cylinders of 40 inches diameter, low-pressure steam-cylinders 72 inches diameter, and air-cylinders each 42 inches diameter, the stroke of the engines being 6 feet. Both the high- and low-pressure steam-cylinders were fitted with expansion-valves, variable by hand whilst the engines were at work. The fly-wheel weighed about 30 tons.

There was also the question of compounding the fan-engines. The ventilating-fans in one of the collieries with which he was connected were compounded, realising considerable saving in coal consumed. The other great point was economy of labour at the surface. That, he thought, was to be obtained, as the Author had pointed out, by properly g ds, taking care that the arrangements permitted, as far , full tubs to flow automatically into the screens or t ts where the coal was to be dealt with, and also the emp utomatically to fall back to the shafts to be reloaded. case, as well as in the case of gradients on the ordinary ra uge, there were two object lessons which might be examine advantage by mining men. One was that shown by the a ces in the Harton colliery, where the cost of labour had bee terially reduced by adopting a very perfect mode of grading roads. The other was at the high-level tips at Barry Docks, wh e Mr. J. W. Barry had shown how much could be done and how e onomically in moving railway-trucks. One point which the Author had not mentioned was the question of dealing with the coal other than making it into bricks, viz., coking. In this direction there had been enormous improvements during the last fifteen or twenty years, especially in the west of Cumberland, where they could now use in some cases for the blast furnaces their own native coke exclusively instead of bringing it from Durham. In South Wales, by the application of the Lührig, the Coppée and other washing arrangements, and the Coppée type of coke-oven, it had been possible to make coke suitable for Bessemer furnaces containing volatile matter as low as 17½ per cent. Until that kind of oven was introduced it had been impossible to make coke from steam small-coal, but coke from this small coal was generally superior to the coke made from the bituminous coals of the district. In a South Wales colliery with which he was connected there were 120 Coppée ovens, each of the following dimensions:—Length, 30 feet; width, pusher end, 15 inches, platform end, 17 inches; height to crown of arch, 4 feet 6 inches. The

Mr. Brown. charge[1] of each oven of washed and crushed coal varied between 39 cwt. and 35 cwt., according to the state of repair of the ovens. The time of burning was twenty-six hours and upwards, but averaged thirty-six hours, according to the dryness of the coal and to the washing, &c. The output of coke per oven was $36\frac{3}{4}$ cwt.

Dry coal	per ton of coke . .	30·26 cwt.
Washed and crushed coal	„ „ . .	27·23 „
Coke to dry coal		66 per cent.

The Author had stated that "the average weight of mineral wrought per workman in the North Staffordshire district is higher than the average for the United Kingdom, the relative figures being 302 tons in the former case and 257 tons in the latter." That bare statement hardly presented the true facts, because in certain coal districts the hewer of coal sets timber and does other kinds of labour besides coal-getting; and in other districts he works the large coal, only leaving the small underground. In Northumberland, where it was notorious that the hewers of coal were on an average stronger and more effective than, for example, those in Durham, the output per man was considerably less than in Durham, because the coal was harder to get in Northumberland, and a portion of the small coal was left underground. He agreed with the Author that the practice of many colliery engineers was too much by rule of thumb. He did not think, with certain exceptions, that sufficient trouble was taken in laying down upon plans and sections beforehand what was proposed, and working to such plans, and the result was that a complete arrangement was not obtained, and the highest economy was not secured. There were, of course, certain districts where it was very difficult to lay down an ideal surface arrangement. In South Wales, where the valleys were very narrow, engineers could not do all that they desired in the way of perfect arrangements. His own practice had been,

[1] ANALYSIS.

—	Coke.	Coal.
Ash	5·025	4·25
Moisture . . .	1·250	..
Sulphur	0·650	0 68
Phosphorus . . .	0·025	0·02

where it was possible, to lay down colliery railway-sidings so that the empty roads should be of sufficient capacity for one day's supply, and the full roads for two days' work of the particular pit to which the sidings relate. With regard to the Author's pit-bank arrangements, he probably had not had an opportunity of considering the experience of South Wales. Mr. Forster Brown had started with a prejudice in favour of small tubs for mining purposes, but he now preferred, where the heights of the coal-seams were from 4 feet upwards, tubs or trams carrying between 30 cwts. and 40 cwts. In one case, within his own knowledge, they had trams carrying 20 cwts. in one pit where between 1,000 and 1,100 tons were raised per day; and in another pit in the same valley, with the same depth and the same power of engine, but with a larger tram, carrying 35 cwts., 1,700 tons per day were raised. That was the result solely of the increased carrying capacity of the tram. As to screening, hand-picking belts were now being introduced in South Wales, and he had had recently to consider a design of belt-screens for dealing with 2,000 tons a day, of which the following were particulars:—The pits were 240 feet apart, and the screen-walls and sidings were arranged between them. The sidings were seven in number, laid out on the "gridiron" system; the centre road being the through return road for empty wagons, and the other roads diverging from this at the upper end and joining it again at the lower end of the sidings. The gradient was 1 in 43. The screen-walls were 24 feet high and 95 feet apart, and connected by a bridge of steel joists supported by cast-iron columns placed in line with the pits. The bridge was 25 feet wide and was covered by a roof which extended to the pits on each side. Upon the bridge four hutch-tipplers were arranged with screens of the type usual in South Wales, beneath them. Two sets of tipplers, screens, &c., were provided for each pit. The full trams, on being landed on the pit-bank, were passed over turntable weigh-bridges of the usual type, and were brought down to the bridge on tram-roads the inclination of which was $\frac{5}{8}$ inch per yard. They were then pushed into the revolving side-tipplers, which were actuated by friction-gear and revolved at the rate of three revolutions per minute. The tipplers emptied the wagons by revolving in a direction opposite to the inclination of the screens. The empty trams were then pushed on to a steam-hoist, placed in the centre of the bridge, which automatically elevated them to an overhead tram-road along which they ran by gravitation to the back of the pit-bank. Mr. Brown.

Mr. Brown. The screens upon which the coal was first deposited had an inclination of 16½ inches in one yard. The bars were 10 feet 6 inches long × $\frac{7}{8}$ inch thick on the top edge, and were set with 1⅛-inch spaces between them. The coal, after passing over the screens, was deposited on a slow-motion band, 5 feet wide and 9 feet from centre to centre, travelling at a speed of 15 feet per minute. The object of this band was to distribute the coal evenly over the hand-picking band. The coal was then passed on to the hand-picking band, which was 46 feet long by 5 feet wide, and travelled at a speed of 45 feet per minute, and by this the coal was as far as possible cleaned from shale and dross. On leaving the hand-picking band, the coal passed over a jigging-screen 4 feet 6 inches long, the inclination of which was about 1 in 5. The screen had a reciprocating motion through 5 inches at a speed of fifty periods per minute. Any small that had been made on the picking-band, or was not taken out in passing over the large screen, was removed by the screen. The large coal then passed down a balanced shoot into the wagon. The small coal removed by the fixed screen dropped into a billy-box of the usual type, and thence on to a conveyor-band 3 feet 6 inches wide. The small coal made in the jigging-screen was also conveyed by small 2-feet bands back to this point. The whole of the small coal was conveyed to an elevator, which raised it to a rotary screen placed over a pair of large hopper-bunkers, each capable of holding 30 tons of coal. The rotary screen, the diameter of which was 5 feet at the small end and 6 feet at the large end, giving an inclination of 1 in 16, had a mesh of ½ inch and a speed of 11 revolutions per minute. The coal was there separated into "nuts" and "small," the small passing through the meshes of the screen into the bunker immediately beneath it, and the "nuts" being conveyed to the large end of the screen, where it fell over a short shoot into the next bunker. It had been proposed that the "nuts," after leaving the rotary screen, should be passed over a short picking-band placed over the second bunker, and a third bunker added. The screens and picking-bands were arranged in double sets, each one of which was fixed immediately over the two sidings next to the screen-walls. By this system the coal followed one direction, and was deposited by a balanced shoot in line with the wagon and not set at right angles to it. That enabled the coal to be deposited with less breakage than with the old method. Each double set of picking-bands was placed in an elevated shed against the screen-walls and was actuated by a horizontal steam-engine with cylinders 12 inches in diameter and 21 inches stroke placed on top of the

screen-wall. The difference between the original arrangement and that carried out was the removal of the jigging-screen from the front end of the band to the shoot-end and the substitution for it of the slow-motion band. The 2-feet conveyors were introduced to carry the small from the jigging-screen back to the elevator. The cost of the bridge, roof, and building for four sets of machinery was about £2,300. The cost of the machinery, including tipplers, screens, a slow-motion band, a picking-band, conveyors, hoists, engine and shafting, &c., was about £4,185. The total cost of the four complete sets was therefore £6,485. Mr. Brown.

Mr. JAMES RIGG would not have risen to speak but for the circumstance that he had been long occupied in the manufacture of machines for tipping and screening coal. Before referring to that subject, however, he wished to invite attention to the valuable invention of Mr. George Fowler, enabling three tubs to be delivered simultaneously, thus releasing the main cage and the winding-engines from work in which they should not be employed, but in which, at many collieries, they were so used, namely, in raising tubs from one stage to another. That was a matter of importance not mentioned in the Paper. Another point was the making up of the coal-trains by the force of gravity instead of that of a locomotive. It was a common practice, in making up coal-trains, to move the empties under screens by means of a locomotive; but it was done at the Whitfield Colliery by gravitation. The empties were lowered under the screens down the proper gradient; when loaded they were removed on a different gradient, and the trains were thus made up without the employment of a locomotive. With reference to colliery workshops, he had long thought that expense was often devoted by coal-owners to the construction of a large establishment for doing work which was not required. They had a staff which must be maintained, and they were, therefore, tempted to incur charges in doing unnecessary work. That expense might well be avoided, and be turned into profit. On the subject of tipping and screening he would not now say much; but he hoped at a later period to offer to the Institution a Paper dealing much more largely with the methods of loading coal of different kinds under varying circumstances and for different purposes. As the Author, however, had in Figs. 9 and 10 given illustrations of a machine with which Mr. Rigg was closely connected, having made between 400 and 500 of them, he wished to say that, from long and entirely unprejudiced observation, his conclusions were different from the Author's. The Author was of opinion that the tipping machine illustrated in Mr. Rigg.

Mr. Rigg. Fig. 12 was the better of the two, because there was a control in its revolution. There was such a control; but a more important matter was that the centre of oscillation should be placed exactly in the proper position, because half an inch would determine the difference between success and failure. Long experience had enabled success to be attained in that respect. The main objection to the revolving tipping-machines was that they threw the coal upon the surface of the screen in an unsatisfactory manner, because, instead of turning it over in the direction of the bars, they turned it against the face of the screen; and the result was that house-coal, which should be tenderly treated, was broken to the extent of 6 per cent., as had been mentioned by Mr. Bainbridge, and in many cases considerably more so. A foreshortened view of the tip shown in Figs. 9 and 10 would make this matter clear. The coal was tipped on to a plate, and slid down and spread upon it, so that it was then fit to enter upon the screen-bars. Figs. 8 and 12 showed that the coal was thrown down upon the bars in a state unfit for screening. The consequence was that it passed down half the screen without being separated, the lower part of the bars alone being useful for that purpose. With regard to screens, he must differ from the Author, who had come to the conclusion that jigger-screens were the best. No doubt they were effectual in separating the slack, and there was only one screen more effectual in this respect, viz., the revolving screen. This, however, the Author had said injured the coal more than any other, and Mr. Rigg considered it the most destructive piece of apparatus that had ever been used in connection with coal. He had seen fine large house-coal enter at one end of a revolving screen and be absolutely reduced to slack on leaving at the other end. For house-coal he had found that a balanced screen, with the bars arranged in a particular manner, produced far more efficient results than the ordinary screen with fixed bars. He had also found that jigger-screens (which he had discontinued making sixteen or eighteen years ago) did not last so long as steel bars. He had further observed that slack might be as effectually separated upon tapered steel bars as upon jiggers, provided only that they were set at a correct inclination, which was a matter of great importance.

Mr. Head. Mr. Jeremiah Head was not sorry to have an opportunity of taking part in the discussion. The Paper would have been worthy of the Institution had it merely professed to be a description of colliery surface-works which the Author had erected and which were in accordance with the best practice of the present day.

But the Paper contained more than that. It professed to give an instance of mechanical evolution. It compared the best practice of the present day in colliery surface-works with that of, say, a generation ago; and also drew particular attention to the advantage, combined with mechanical efficiency, of concentration of efforts, of buildings and of arrangements, as against diffusion. Those principles were applicable not only to colliery surface-works, but to almost every industrial organization. Experience showed that in a certain time—ten, twenty or thirty years—all those organizations had to be entirely replaced by others of a totally different nature. Happy were those who, foreseeing and appreciating at their full value the contingencies of the future, laid by a certain amount every year for depreciation and put it into some safer place than the shareholders' pockets, or did not apply it to any mere multiplication of what they had before; so that when the inevitable time for replacement came, the money was there for the purpose. Happy also was the manager who had the opportunity of laying out works in accordance with the science and the best practice of the day, and unhampered by any of the unfavourable conditions which attached to old concerns. He was not quite clear whether that had been the Author's case or not. He rather gathered that the Author had been to some extent impeded by old arrangements, and perhaps he might have done still better but for that circumstance. It was a very serious obstacle to the renovation of such works if they had to be carried on while alterations were progressing, because, among other things, there was sure to be a certain amount of opposition from the workmen and others employed. That subject had been alluded to in the Paper. The object of the Author in making his very successful arrangements had been to get, say, each 100 tons of coal with less cost for labour. It was known from experience, especially from what had happened in the coal trade during the last three or four years, that organized labour always sought to increase the wages paid for every 100 tons of coal obtained; there was, therefore, that opposition always to encounter. He would not, however, yield to the temptation of going into economic subjects, however he might desire to do so. It should be remembered that Englishmen had been pioneers in colliery works as well as in railways, steam-engines and many other things; it was not therefore at all surprising that, even at the present day, there were in Great Britain a considerable number of collieries which were as far back in their appliances as those to which the Author had alluded when contrasting his own work with them. It would, perhaps, Mr. Head.

Mr. Head. be scarcely believed what crude appliances there were in some of the older districts. Only a few months previously he had been at a colliery where there was a winding-shaft, and the winding-engine had no eccentrics and was not even automatic. A man stood with a lever and worked the slide up and down at each stroke of the piston, just like the engine-man in a Shields tug-boat, when he had unhooked the eccentric in order to go backwards. In another part of the country he had seen, not a long time ago, some plain cylindrical boilers on which there was no sludge-cock whatever; the sludging and emptying, when necessary, was done by knocking a taper plug from the ash-pit upward into the boiler, the sludging arrangement being merely a hole in the bottom of the boiler with a taper plug driven from the inside. Those were working, to the best of his knowledge, at the present day. At collieries in England were to be found some of the most wasteful engines that existed anywhere; not only because the steam was admitted nearly to the end of the stroke, but because there was often, indeed generally, far too much clearance at each end of the stroke; and very often the cylinders and boilers, with long ranges of steam-pipe, were totally uncovered; also because, from the condition of the boilers, they were obliged to work with steam at a very low pressure; and it was well known that to work without condensing steam at not much above atmospheric pressure was the most wasteful thing that could be done in steam-engine practice. With regard to the arrangement for shunting by gravity, which had been so much admired, that system of shunting and arranging was not new, because it was to be found on several railways, and Mr. William Cudworth had read a Paper[1] before the Institution in which he had described a set of sorting sidings on the North Eastern Railway at Newport-on-Tees, carried out entirely on that system. He should be glad if the Author would state whether such a large quantity as 2,000 tons a day was not trying the weighing-machine too much, and whether it would not be an improvement to have a duplicate one on the other side of the house. He would also ask whether the platform of the weighing-machine was inclined. The weighing-machine itself must, of course, be level, or it would not weigh correctly. If the platform was not inclined, it appeared to him that it would be difficult to send forward the trucks one by one as they were weighed. With reference to the question of repairs being done at the colliery or not, he was disposed to agree with the

[1] Minutes of Proceedings Inst. C.E., vol. xli. p. 19.

Author that no high-class engine-building or engineering work ought to be undertaken there. The colliery was not the right place for elaborate mechanical engineering operations; not only so, but a colliery manager had quite enough to do to attend to his proper work and his own men, without touching the higher branches of mechanical engineering. If he had a hobby that way, and kept highly skilled and highly paid men, in case they should be wanted for special purposes, he might often have them doing almost nothing. At any rate, at all collieries the repairs that must be done were considerable. With regard to appliances such as creepers, tippling arrangements and screens, what struck him was that, considering the large outputs now reached—such quantities as 2,000 tons a day—definite mechanical apparatus must be used for all those operations; in place of depending upon gravity. With properly contrived mechanical apparatus it was possible to know precisely what was being done, to always depend upon it, and always calculate on what it would or would not do. But if gravity alone were relied upon, whether in shunting or letting the coals roll down on the screens, it was necessary to make an inclination sufficient for the worst circumstances; and then it was apt to be rather too much for average or good circumstances. The same thing was seen in ventilating-fans, which in England had almost entirely superseded in well-arranged collieries the old plan of up-cast and down-cast shafts with furnace ventilation. The latter could not always be relied upon, because its action varied with the barometrical pressure of the air. Nothing had been said in the Paper about a great many things usually found among the surface plant at collieries, such as pumping-machinery, fans and compressors, which were often used where underground coal-cutting machines were in operation. Nor had anything been said about electric installations at the surface. Such things were becoming of more and more importance, for a very large proportion of the coal-seams now being worked were not more than 26 inches thick.[1] That circumstance was likely to have a marked effect on coal-mining operations by hastening the introduction of machines for the purpose in cases where the work had previously been done by hand labour; and the working of those machines in the mine meant auxiliary appliances at the surface. It had been mentioned that in the colliery described in the Paper iron ore was brought to the surface, which was still the case in Staffordshire, South Yorkshire, Scotland, and other places; Mr. Head.

[1] North of England Institute of Mining and Mechanical Engineers: President's Address, Dec. 8, 1894. *Iron and Coal Trades Review*, Dec. 14, 1894, p. 745.

Mr. Head. but the Author was silent about any special means for calcining or otherwise dealing with it. He did not, however, forget the sage remark made at a recent meeting of the Institution, that it must not be supposed that readers of Papers were going to tell everything they knew in the course of one short Paper. He had no doubt, therefore, that what the Author might have said further on other subjects, he had reserved for some future occasion.

Mr. Peake. Mr. H. C. PEAKE was glad to have had the opportunity of hearing the Paper. The arrangements described did not leave much room for further saving in the surface costs, but there were still a few minor points to which some attention might be given. The greatest saving would be in the depositing of coal on the screen so as to save breakage as far as possible. The alteration of an old place, as in the case the Author had described, was very different from designing a new one, there being many details in an old place which, though not quite modern, could not well be altered. For instance, an improved way of doing something would probably cost £100 or £150, and when done would save £10 a year. At a colliery where not only interest had to be paid, but also a sinking fund provided, a saving of £10 or £100 or £150 was not enough; it would not repay the cost, and that was a great difficulty which mining engineers had to meet. The gridiron sidings described were admirable, working easily and economically, and could not be improved. Another thing, however, had to be considered, viz., dealing economically with the coal on the bank, especially where there were two or three screens to deal with, and it was desired to deal with them as near to the pit top as possible. In some cases, by adopting a platform wagon or traverser to work at right angles to the screen roads, it might be dealt with much nearer to the pit top quite as economically as the Author had stated. It was impossible to provide gradients for automatic shunting suitable for all trucks. What was only sufficient for a bad-running one was too much for a good-running one. The Author was somewhat heroic in the gradient of 1 in 30 that he laid down as being the one for shunting. As the result of a great deal of experience in automatic shunting, he generally found 1 in 80 actually enough for all practical purposes. Almost any wagon would start on that gradient, and a heavier gradient damaged the wagons very much, seeing that they sometimes ran into each other. With regard to the improved pit-tubs described by the Author, Mr. Peake had been working on that question for twelve months past, and was now replacing the old wooden tubs with steel ones put together with thin steel plates

Mr. Peake.

fastened merely with bolts to the uprights, which consisted of channel-steel bars, and had all the advantages claimed by the Author, being easily taken to pieces for repairs. As to the size, he was inclined to think that tubs carrying between 12 and 15 cwt. were most suitable to the seams and method of working in his district (Walsall). In South Wales, the authorities seemed to say that collieries working with trams of 30 cwt. and 2 tons paid the best. It appeared to him that it was not so much the trams as having seams with the roof and conditions capable of using those large trams that made the difference. The gradients of the pit-bank roads alluded to in the Paper were much steeper than Mr. Peake had found necessary. For loaded tubs he had laid down a rule of 1 in 72, or half an inch in the yard on the straight roads, and 1 in 48, or three-quarters of an inch in the yard on curved roads. That seemed to answer perfectly, and had the same advantage with regard to the gradients on the truck-roads of not damaging the tubs quite so much as a heavier gradient would do. In Fig. 5 he suggested that if the Author substituted some spring points beyond the tippler, if there were room, in place of the plate, he might save a man, and so work rather more economically. As to the tipplers, the Rigg type was one of the first designed to save breakage of the coal. Mr. Peake had had some twenty-five years' experience with that tippler, and it was a very good one. At the same time it was getting somewhat out of date. Every tub had to be pushed on to it and then pulled off, which was hardly compatible with modern requirements. The Author was more on the right lines, but it might be found that the tipplers of his design broke the coal rather too much. If he continued the side-plate (Fig. 11) further, and curved it with the frame of the tippler so that the coal fell on to it before getting on to the screen, and did not begin to fall on the screen bars until it got into the position shown on Fig. 12, it would save a considerable amount of breakage. With regard to the Lyall screen, the Author seemed to have formed a wrong impression; in fact, his description of it was hardly accurate. The screens were fixed in alternate directions, one over the other; so that the coal passing through the larger screen, which was on the top, was dealt with by the next, which sloped in the contrary direction, then by a third sloping in the same direction as the first. When once on the screen, the coal was dealt with most tenderly, flowing down always in a straight line like a stream of water, seldom touching the sides. The riddles moved under the coal, merely turning it over and rubbing off the loose edges. The screen itself only weighed about 7 cwt., for a

Mr. Peake. four-quality one capable of dealing with about 500 tons in eight hours; that was in addition to the riddles, which weighed $1\frac{1}{2}$ cwt. each. One great advantage was that the largest sized coal passed off the riddles first, and that was of considerable importance, because the large coal took more harm in dealing with than the small. In conjunction with a picking-belt he thought that was one of the best screens that had been introduced. The results, so far as breakage was concerned, compared most favourably even with fixed screens. The Author had apparently observed some difference in action between cranks and eccentrics for driving and shaking the screen; but, although he had had to do with both, he could not detect the slightest difference. They seemed to be only different ways of arriving at the same result; the only question was, whether to adopt eccentrics, in which there was the most friction, or cranks, which were most liable to breakage. The Author appeared to have left out any mention of the use of picking-belts, which seemed at the present time almost a necessity at a colliery. As to the winding-appliances of Walsall Wood Colliery, as mentioned in the Paper, the time had been somewhat reduced since the Author had obtained his information, and the output had been consequently increased. The probability was that the new plants would in future be fitted with high- and low-pressure cylinders and automatic cut-off arrangements. A fixed cut-off made engines difficult to handle for shaft repairs, or at any time when not running at full speed; but the automatic cut-off would effect such a saving in fuel that in new and deep collieries it would become almost a necessity; especially as the initial cost, taking into account the saving in the amount of boiler-power, would be little more than that of the present type. Some idea might be formed of the saving by referring to a Paper by Mr. J. Daglish,[1] in which it was shown that in consequence of excessive back-pressure in running with steam at a full-length stroke, the diagram was larger when an automatic cut-off was used, cutting off at two-thirds of the stroke. That would mean that two-thirds of the boiler-power would suffice. The balance-ropes were very good, but if water had to be drawn they could not well be put under cages without some complicated arrangement at the pit bottom. In such cases it paid to have a perfectly independent balance arrangement, consisting of a light carrying-rope passed round a groove in the centre of the drum, and working with a heavy balance-rope. This latter should be equal to the weight per yard of the winding-rope added to that of the

[1] Trans. North of England Institute of Mining Engineers, 1879, vol. xxix. p. 3.

carrying-rope and working the exact depth of the shaft, so as to come up with each cage. That was practically the same as the old North of England balance-chain arrangement. Reference had been made in the Paper to the Koepe system; with the lining of two hemp ropes properly laid in the groove there was not the slightest slip of the rope. As the weight came on to the rope, it bedded itself in the lining, and the more stress there was the better it held. He had had experience of one and had found the wear on the rope was very small. Mr. Peake.

Mr. R. Price-Williams said that, having been identified all his life with coal-mining operations, he welcomed the Paper as a valuable contribution to the Proceedings of the Institution, as twelve years had elapsed since the comprehensive Paper of Messrs. Forster Brown and Adams had been read.[1] He considered it would be fortunate for the interests of the greatest industry Great Britain possessed, and the sources of its power in more senses than one, that the Paper under consideration should be supplemented by one on another equally important branch of the subject, viz., underground working of collieries. Mr. Price-Williams.

In the few observations he had to make, he intended to deal with some of the remarkable economic results obtained by the Author through the skill he had exhibited in improving the arrangements for surface-working, in the saving effected by utilizing the force of gravity in place of the haulage of the empty trucks and in other ways. If the figures given by the Author might be relied upon, and he saw no reason to doubt their accuracy, the saving he had thus been able to effect in the surface-working expenses by concentration, by improved mechanical appliances, and by the reduction of the cost of haulage, amounted altogether to as much as *4d.* per ton, which, as the Author had stated, was about one-twelfth of the whole cost of the surface- and underground-working at the present time; this very appreciable reduction in the cost of getting coal was highly satisfactory and offered every encouragement to effecting further economies both above and below ground. The ratio of the working expenses to the price of the coal at the pit's mouth, which was nearly 60 per cent., struck him as being largely in excess of what it ought to be; and he desired to impress upon the repesentatives of the coal-mining industry the great importance of effecting those further large economies that there was everything to indicate might be accomplished in

[1] "Deep Winning of Coal in South Wales," Minutes of Proceedings Inst. C.E., vol. lxiv. p. 23.

Mr. Price-Williams. underground workings, more especially when opening up new collieries.

The Author had explained that the small size of the wagons or tubs in use at collieries in the Midland Counties, which only carried about 10 cwt. of coal, was due to the small height of the seams worked; but he ventured to think they were unnecessarily small, and he felt sure mining engineers from the South Wales District would bear him out that in working seams between 3 feet and 5 feet thick coal-wagons of much larger size were used, those for instance at the Risca Colliery having more than double that capacity, viz., 1 ton 8 cwt. The great economy resulting from increased capacity of coal-wagons was strikingly illustrated in the Paper, where it was shown that by substituting steel plates for the bottoms and sides of these small wagons, of the thickness of $\frac{3}{16}$ inch and $\frac{1}{8}$ inch respectively, in place of the $1\frac{1}{2}$-inch and $1\frac{1}{4}$-inch board, the carrying-capacity of each wagon was increased from 10 cwt. to 12 cwt., equivalent to an increased output of 200 tons a day where 2,000 wagons were used; here alone it would be seen there was a wide field for the economising of colliery working.

The enormous waste of power in both surface- and underground-working of collieries in England, as well as in the Australian Colonies, was, in his opinion, highly discreditable to the engineering profession; and it was needless to say that this waste of power resulting from badly laid and worse maintained tramways in the main roads underground, the imperfect appliances used where mechanical haulage was employed, and the waste of life and energy where horse haulage was used, was necessarily attended with a proportionate increase in the cost of colliery working. Having regard to the importance of the subject, he hoped that the present Paper would soon be supplemented by one either by the Author, or by some one equally capable of dealing with the subject, on the underground working of collieries.

Mr. Brough. Mr. Bennett H. Brough said that it was interesting, in view of the Author's advocacy of an increase in the number of decks on a colliery cage, to consider what was being done in that respect on the Continent. During the recent visit of the Iron and Steel Institute to Belgium, a number of collieries had been visited, and opportunity had been afforded the members of observing modern continental practice. One of the most interesting installations visited was the colliery at Marchienne, where, instead of having two decks to the cage as described by the Author, or three decks as described by Mr. Bainbridge, the cage had as many as twelve decks. In that case the shaft was of enormous depth, extending

to as much as 3,100 feet, and at the same time it was of small diameter, 10 feet, so that, in order to obtain a large output, it had been necessary to have recourse to the system of increasing the number of decks. The cages were 50 feet high; they weighed 4 tons and carried one wagon on each deck. Another point to which he desired to draw attention was the Author's classification of the various mechanical screens into three classes. That classification, he ventured to think, was not quite complete. There was no reference to the Briart screen or other movable bar-screens. The omission was perhaps due to the fact that that screen had been fully described in a Paper[1] read before the Institution during the last session by Mr. R. E. Commans, and also in a Paper[2] read in 1882 by Mr. T. F. Harvey on "Coal Washing." In order to render the present valuable Paper thoroughly complete, it might have been as well if the Author had seen fit to introduce a reference to screens of that type. Mr. Brough.

Mr. T. Clarkson desired to say a few words in reference to the subject of screening. As the Author had said, a Paper might have been written on that subject alone; and it might even be said that volumes could be written on the subject without exhausting it. It was an indication of the importance of screening that about one-fourth of the Paper was occupied in dealing with the subject, and it was also an indication of the Author's care in preparing the Paper that he had described no less than seven different kinds of screens. In regard to the kinds of screens, it might be said that the number of screen mechanisms was legion, and it was perhaps impossible even to enumerate them in one Paper. In considering the various screening arrangements it was somewhat perplexing to try and arrive at some definite guiding principle in their design. It frequently seemed to be thought that there was special virtue and efficiency in some particular kind of shake. The side shake, the end shake, and a combination of the two had been advocated, while the vertical element had also been introduced, but so far as he knew the reason for the various motions had never been explained or investigated in a proper manner. He desired to say a few words on the subject of the theory of screening. In the first place let an ideal screening performance be conceived. Let it be supposed that there were some large lumps of coal, and, instead of fine coal mixed with it, water or any other liquid. It was well known that if such mixture was placed upon the screen, Mr. Clarkson.

[1] Minutes of Proceedings Inst. C.E., vol. cxvi. p. 8

[2] *Ibid*, vol. lxx. p. 106.

Mr. Clarkson. the liquid would at once pass through and leave the lumps behind. That was precisely what ought to be the case in screening a fine from a coarse material. Immediately the mixture was placed on the screen, the method of agitation should be such that all the fine stuff would immediately pass through, without any undue knocking about of the lumps. The reason why crushed solids did not act in the same manner as liquids, was simply that there was friction between the solid particles. Friction, as was well known, was simply the effect of the inter-penetration of minute projections on the touching surfaces, and the question arose, How could that friction be best reduced? The ordinary method of reducing friction by lubrication or by converting sliding into rolling friction, did not, in the present case, seem to be applicable. Therefore recourse was had to vibration. If the touching surfaces could be agitated in such a manner as to prevent the inter-penetration of the projections, friction would practically cease. The question was, How was vibration to be obtained in the most efficient manner without wasting the power and unduly knocking about the stuff? All the various mechanical contrivances which had been described were simply attempts to produce vibration. It had been pointed out by the Author that he had found that a short stroke and a more rapid one was the more efficient. That was exactly what one would expect, because it was not the actual movement of the screen that was the efficient point in sifting, it was the jar or vibration set up at the reversal at each end of the stroke, and what was really wanted was to maintain that jar continuously. It was not necessary to consider the motion about the middle of the stroke, as this was of little utility for screening purposes, and mainly had the effect of breaking the coal by impact of the bars, and in causing much attrition of the screen-surface. Rapid succession of small jars was required, so as to keep up the intense vibration. At first sight it seemed impossible, or at all events impracticable, to have a high vibration, say 1,000 or 1,500 per minute, with a stroke of a quarter of an inch under the conditions prevailing on colliery surfaces; but he thought that by modifying the mechanism it might come within the range of practicability. It was certainly impossible to do it by the use of an ordinary crank and connecting-rod. He thought an ordinary hexagonal pencil pointed the way to a solution. The effect of rolling it between the hands or beneath the feet was to set up an intense vibration of very small range, but very rapid. He had tried experiments for a considerable time under various conditions with polygonal rollers, the number of sides varying from five to twelve,

and he had found that the mechanism was remarkably efficient as a screen device. It had the advantage that the motion was not only rapid, but was in a direction perpendicular to the plane of the sieve, which was very important and much more efficient than a rapid, horizontal vibration. In one case some few polygonal rollers were simply placed in a light frame, and the box carrying the sieve rested on the top and moved slowly backwards and forwards. He had placed on the table a model of the arrangement designed to show the polygonal roller applied to continuous working. There was a flat screen frame supported at the front end on a fixed bar, and at the other end there was a roller with eight sides. Beneath there was a plane-wheel upon which the polygonal roller rested. That was all the mechanism there was about it. The effect of giving a slow motion to the wheel was to impart a very rapid vibratory movement to the screen. One advantage of the motion appeared to be that there were no high speeds in the bearings. It was only right to mention in this connection Mr. Beaumont's very ingenious arrangement for vibrating by means of an out-of-balance lever; but he was afraid that in a case of that kind, where such high speeds in the bearings were required, a vibration of 1,000 or 1,500 per minute, such an arrangement would be out of the way in collieries, and in addition the horizontal vibration employed was not so good. The polygonal roller enabled them to get a low bearing speed combined with very rapid and intense vibrations. There appeared to have been a want of system in the design of screens, there being no definite principle underlying them. No one could explain, except by rule of thumb, why a particular motion was most efficient; and instead of having such a multitude of mechanisms, if they could get upon some general line, and see what was actually necessary, they would really progress. Mr. Clarkson.

Mr. W. W. Beaumont proposed to refer only to the part of the Paper which the Author had described as most important, and to which Mr. Clarkson had addressed himself. He did not intend to refer to his new mechanism that had been mentioned, because it was already well known and largely used. He would only refer to the question of screening as one that ought to be considered with reference to what had to be done to the material to be treated. In the ordinary way screening was a process of roughly shaking the material to be dealt with by something that would let as much through the screen as was possible during the travel of the material. Ordinarily the shaking was brought about by cranks, eccentrics, and the like, or Mr. Beaumont.

Mr. Beaumont. by something that jarred the screen, and necessarily jarred or violently jerked the material to be treated, causing it in the one case to knock itself to pieces by particle hitting particle (which, with tender coal, as the Author had mentioned, produced a large amount of waste), or causing a very great amount of wear and tear in the machinery employed for the purpose. Generally both those things happened. He wished to refer to what happened on screens as ordinarily made. It would be seen, on watching an ordinary screen used for granular material of considerable size, with a stroke of say 3 or 4 inches suitable for material of small dimensions, that in the case of any piece of the material resting on one bar out of five, instead of that piece dropping from the bar through the hole next to it, the quick movement of the screen, with the long travel, caused the piece to be caught by the next bar, and the next and the next, and so on, dropping through the hole probably nearly at the full length of the stroke of the screen away from the hole through which it might have dropped, if the stroke of the screen had been proper to it. Not only did that cause a great deal of waste of power in operating such screens, but it caused the material that was being moved in the screen to surge backwards and forwards with it, and every stroke of the screen caused every lump of coal to hit every other lump of coal, with the result that the corners of the lumps were knocked off and more small coal was produced. Instead of using the long strokes, and carrying the material in a screen, the screen should really just move underneath the material without moving it much. The screen should only be moved a distance horizontally which was necessary for each bar to get out of the way, and let the piece upon it, which was small enough, drop through. That not only had the effect he had mentioned of economising power, and the prevention of breaking the coal, but it at the same time prevented the performance of a lot of unnecessary work, and it increased the capacity of a given area of the screen. It had been mentioned by the Author that it was necessary to have in connection with the screen plant very considerable repairing power. There was no wonder at that when they remembered the tremendous jerking and hammering of the screens and screen frames which took place with screens worked in the ordinary way. It was impossible to keep those things, under the conditions of colliery-working, in the nice condition that rapidly moving screens were kept in, for example, flour mills. The result was that the smallest wear would soon set up a very rapid deterioration, and there was lost motion, as it was called in America, or slackness, which caused the hammering,

jolting and jarring to the screen,—a movement in fact which had fallaciously been referred to as more or less a necessity. It could be shown that it was not jarring that was wanted, it was a movement of the screen in such a way that it should let the materials that were small enough pass through it without such jarring. The jarring did harm. The impact movement caused by any of the ordinary methods made it necessary to give greater strength to the screens than would be required if they could be worked without. He had shown in that room on a previous occasion[1] how screens could be moved under the material to be treated, letting the material rapidly through, the screen itself working without any jarring movement whatever. The reference by the Author to what had happened with a rotary screen was a confirmation of what had been stated by Mr. Beaumont with regard to the breaking of the material. It was not the length of the stroke, but the number of reversals, the number of opportunities that the piece of material might have to go through, that was the important part in the working of these screens. One hundred strokes per minute and 4-inch to 5-inch stroke had been given by the Author, which gave only 200 reversals per minute, but for average small material Mr. Beaumont had adopted not more than 1¼-inch stroke, which at 300 revolutions per minute gave 600 reversals. The screen had an output which was increased roughly in proportion to the number of reversals. It was not only that the capacity of the screen was in that way increased, but everything connected with it wore for a much greater length of time without any need for repairs. Mr. Beaumont.

A further point was that it was not of much use to do the very best in connection with the formation and working of the screen itself, unless the proper feeding of the screen was secured. No screens could work properly that were not carefully fed. No screen, for instance, that had at one moment a tub full of coal and was at another moment empty, could possibly do its full amount of work or its duty by the coal. In the one case the coal was surging and being knocked to pieces, the screen really becoming a comminuting machine for the time being, and at the other time it was doing nothing; at one time the screen was checked and strained under the load, at another earning nothing. It had been stated that there was a great deal of rule of thumb in designing surface-plant, and that it had not been considered necessary that great care should be taken in connection with the surface

[1] Minutes of Proceedings Inst. C.E., vol. cxvi. p. 80.

Mr. Beaumont. machinery in the action of screening. It was now, however, becoming a most important thing to grade the coal, which was with so much trouble dug and brought to the surface. It was not only that the material itself was increased in value, but that which was of little value could be used for purposes for which it had been hitherto useless. The delivery on the screen, as had been shown in the diagrams, was of the roughest kind. It was as necessary, especially for tender coal, to put it not only through the screen, but into the screen carefully, as it was to deal with the material in flour-mills. He knew from experience that those things could be done, so that the coal might be treated without, firstly, requiring the power that was now necessary; secondly, without knocking the coal to pieces, as was now done; thirdly, without that great wear and tear requiring such large workshops; and fourthly, it might be done so as to greatly increase the value of the materials that were now put on to the surface and roughly treated by the present somewhat inferior surface-plant.

Mr. Heenan. Mr. HAMMERSLEY HEENAN said he would like to know exactly Mr. Beaumont's opinion on one point. He had seemed to say with absolute certainty that with a $1\frac{1}{2}$ or $1\frac{3}{4}$-inch stroke, making 300 revolutions a minute, less damage would be done to the coal than with a 5 or 6-inch stroke making 100 revolutions. The injury done to soft coal would depend upon the velocity with which a piece of iron struck that piece of coal. As the coal could only come into contact for one moment, Mr. Beaumont's quick motion would appear to hit three times as great a blow against the coal as the slow motion of 100 revolutions. Having paid a good deal of attention to coal-screening, he always found that the slower the stroke the less damage was done to the coal.

Mr. Dolby. Mr. E. R. DOLBY thought that a law might be deduced from Mr. Beaumont's remarks to the effect that the length of the stroke should exactly equal the width of one of the bars, supposing the material to be screened was moving in the same direction as the bars were lying, because that would just bring the bar from underneath the particle lying on it. It would also appear that the opening between the bars should at any rate be never narrower than the bar itself. The movement of the screen would be at right angles to the bars.

Mr. Mills. Mr. MANSFELDT MILLS wished to make one remark. Londoners, unfortunately, objected to dirt in their coal, and the great difficulty was in taking the dirt out of the coal. Screens were of no value, unless arrangements were made for cleaning the coal; the greatest difficulty would be found in cleaning the coal

so as to fit it for the London market unless a belt was used. That was a point that had to be thought of considerably more, unfortunately, than the actual screening. Mr. Mills.

Mr. BEAUMONT wished to reply to a question asked by Mr. Heenan. Taking the figures given by the Author, the stroke and speed gave 1,000 inches of travel per minute, whereas the revolutions and the stroke mentioned by Mr. Beaumont gave 600 inches and twice the number of reversals. Mr. Beaumont.

Mr. WAIN, in reply, said he had only given what was after all a very sketchy outline of some of the more important colliery surface-works, and a better title to his Paper would perhaps have been "Some Colliery Surface-Works." It had not been his intention so much to give details of his own personal experience as to illustrate typical colliery appliances; and if he had mentioned any particular colliery or apparatus, it was not to call attention to it as being of exceptional interest, but rather because he had made use of such illustrations as were most familiar and came readily to hand. Neither could he claim that all the appliances and arrangements specially mentioned were of original design; they must be taken rather as applications and adaptations of known principles in colliery engineering. When it was remembered how absolutely every industry depended on the success of coal-mining, it would be felt that too much stress could not be laid on the importance of a careful application of the principles of civil engineering to mining work. The subject was a very large one, and it was not possible within the limits of a single Paper to deal exhaustively with the requirements of colliery work; in fact, any one of the details of the sections of the Paper would afford room for very considerable discussion. The tippler which had been specially commended by Mr. Bainbridge was of the Heath-Woodworth type (*Fig. 13*). That tippler had a positive action, and the speed could be absolutely regulated. He believed there were only two tipplers with a positive action—the Heath-Woodworth, which was an end-tippler, and the Wood-Burnett, which was a side-tippler. In the one case the positive action was gained by the use of cogs, and in the other by the chain and sprocket-wheel. Both machines had good qualities, and although he had given an instance of a typical side-friction-driven screen, he had no hesitation in saying that the positive action was best. In a friction-driven screen there was a point in the revolution when the force of gravity overpowered the friction-wheel, and the coal was deposited on the screen perhaps a little harder than it should be. Exception had been taken by Mr. Rigg to the side-tippler because Mr. Wain.

Mr. Wain. it did not put the coal on the bars in the same direction as the bars ran. In every single instance illustrated in the Paper a plate on a low gradient was placed under the tippler, leading to the screen, and down which the coal had to pass before reaching the bars, so that between the time of the coal leaving the tippler and reaching the screen it had time to get the proper direction. Reference had also been made by Mr. Rigg to the balanced fixed-bar screens, and no doubt these were admirably adapted for dealing with a limited quantity. Nobody could say they were not more durable than jigging-screens; but for the large outputs that had to be dealt with in colliery work jigging-screens were a necessity. That was generally admitted; and although the cost in wear and tear was heavy, still, if properly constructed in the first instance, the cost was small in comparison with the saving resulting from the use of such appliances. In his communication on the screening at Caerau Colliery, Mr. Forster Brown had mentioned the question of the delivery of coal into the wagons. Figs. 14–17 showed that the coal was delivered at right angles to the wagon. The delivering of the coal in the same direction as the wagon and saving considerable breakage had been referred to by Mr. Forster Brown. He quite agreed in that respect; and in a screen erected by him some four or five years ago on the same principle as Fig. 17, the coal was delivered into the wagon in the line of the wagon itself, and not at right angles. The only difference between that screen and the one shown in the diagram was that it was set parallel to the line of rails, and short picking-belts carried the cobbles and slack to their own trucks. With respect to compound working and condensing as applied to colliery winding-engines, he had no doubt as to the economy of such arrangement. What he had wished to point out was that intermittent working with a variable load rendered all complication undesirable and prevented full advantage being taken of such methods. Condensing-engines as applied to colliery-winding had been mentioned by Mr. Forster Brown, who said he had a pair working in South Wales giving excellent results. The particulars of those engines would be very interesting, as he believed they were the only instances of modern mining engines working compounded. The railway weighing-machine had been referred to by Mr. Head. No doubt it was actually weighing as much as 2,000 tons a day, and the coal was coming over during the working hours in a fairly continuous train. The weighing-machine plate was set level, with a fall on to and from it; and by careful regulation of the braking of the wagons, and a man on each side of the weighing-machine plate, it was quite

possible to stop the wagon dead on the machine plate without having tight couplers. Not much experience was required, and strange men could soon learn to handle the trucks. The saving of one-twelfth had been spoken of by Mr. Price-Williams. Mr. Wain did not mean to convey that impression. He had said that the cost of surface labour might, with proper appliances, be reduced to one-twelfth of the total labour-cost of working the coal, and that was a fair estimate. He knew in practice it could be done, and done thoroughly, the coal being sent out in a thoroughly marketable condition, with appliances such as he had described. An average working cost of 4*s.* per ton had also been referred to by Mr. Price-Williams. He supposed that the figure given was the cost of labour for surface and underground work, and in addition there were many items, such as royalties, stores, general charges and depreciation, which left but a narrow margin between the cost of production and the selling-price at the pit's mouth. His object had always been to get the slowest and steadiest possible movement on the screen. Fig. 17 represented perhaps the most original of the appliances shown. The screen had a very low gradient, 1 in 14, and by an intermittent reciprocating movement the coal was passed over very steadily. It had been suggested that the openings should be about equal to the throw of the cranks, and in practice they were made so as nearly as possible. The coal lay on the almost horizontal plate, and was gently worked forward. In that instance, as in the tippler which had been commended, there was more or less of a positive action. The apparatus described by Mr. Clarkson was simple and effective, and was, he believed, one which might with advantage be applied to coal-screening. A too regular swinging motion was of no service at all, and there must be some little shock or jar if the smaller particles were to be effectually separated from the mass of broken material. For this reason he had advocated the use of cranks in the construction of coal jigger-screens. The most effective screen he had ever used was one in which the moving pans were connected direct to the main shaft of the engine by means of cranks and side rods; but the wear and tear was too great, and the screen had to be discarded on account of the constant breakdowns. Mr. Clarkson's method was ingenious and decidedly practical, and would be of service for separating the smaller particles, such as slack from nuts, although he was doubtful whether it was, in the form described, suitable for dealing with the large coal, as there would be a tendency to set up a stamping action between the large lumps and the smaller

Mr. Wain.

Mr. Wain. pieces lying underneath them. As regards the "creeping" bar-screens of the Briant type mentioned by Mr. Bennett Brough, he was not aware that such screens were being worked at all in English collieries at present, nor did he think that as regards efficiency or economy they could be compared with the jigging-screens, unless it was for dealing with wet small coal and with limited quantities. He thanked the members for their kind expressions with reference to the Paper, and could only repeat that more credit had been given him than was deserved.

Correspondence.

Mr. Bartsch. Mr. W. J. Bartsch, of Cologne, wished to supplement the Author's remarks on coal-washing by a description of a compound coal-jigger of his own invention. The machine consisted of several combined coarse-grained sieves, each compartment having four automatic discharges for coal, mixed products, and shale. The mixed products from the sieve passed through horizontal double slides to a worm which delivered the material to an elevator. The mixed product was removed by means of that elevator to the rolls, the crushed material passing to the sieves, where the clean coal was separated from the shale. As, however, clean shale settled on the sieves it had to be removed separately through openings for the purpose, from which it passed to the worm, and so on to the elevator, which also removed the fine shale passing over from the sieves. If the discharge openings and the worm were omitted, the pieces of clean shale passed over with the mixed products to the rolls. The consequence was that in crushing a considerable amount of slime was produced, which clung to the coal and destroyed its bright appearance, and reduced its market value. In order, therefore, to retain the bright appearance, two further discharge openings were arranged for continuously removing the fine shale that passed through the sieve, thus preventing the slime from rising above the sieve, and from mixing with the coal. All the discharge openings could be simultaneously operated by a single lever. One of the worms was accessible from above, and the other through openings in the casing. In these jigs, the elbow-joint movement was employed in preference to the eccentric, as the strokes were long (2 inches to 5 inches) and the number of revolutions small (50 to 90 per minute). A more effective action was thus obtained. A further advantage of this method of driving the piston was that the motion was in a straight

line, and the wear and tear of the piston on the sides was not so great as when eccentrics were employed. A piston driven by this gear had a quick downward and a slow upward movement, so that a better separation of the material on the sieves was effected. The stroke was adjustable, and the number of revolutions was arranged to suit the size of the material to be treated. Mr. Bartsch.

Mr. W. E. BENTON observed, with reference to the Author's statement that the amount of coal consumed in British collieries was probably not less than 5 per cent. of the total output of the kingdom, or about 9,000,000 tons annually, that he believed the Author had understated the quantity, and he knew some collieries where 10 per cent. of their output was consumed. In the erection of new collieries great fuel economy was possible. It had been rightly observed by the Author that economy of fuel might be secured in compound cylinders, expansion-gear, condensing exhaust-steam, and in balancing pit-shaft ropes. There were also other important sources for economy in colliery fuel. For example, in colliery steam-boilers he had sometimes found the temperature of the escaping gases higher than the melting-point of tin. This waste of fuel arose either from indifferent stoking, incrustation from feed-water, or imperfect design of boilers. The Lancashire boiler was the most generally used, but it was yet to be ascertained whether it was the best form of boiler for compounding pressures and for a feed of condensed steam. Economy in colliery fuel resulted also from heating the feed-water to high temperatures, and from placing all the stationary engines at the shortest possible distances from the boilers. In some instances the engines might all be conveniently placed in one house, and fuel might thus be saved as well as labour when the pits were not at work. The type of engines also influenced the economy. The triple-expansion vertical engine was suitable for all colliery purposes except winding. He was of the opinion that, in the erection of new collieries, the mining engineer might copy with economy much of the practice of the marine engineer. The consumption of coal at collieries was sometimes as much as 8 lbs. per I.HP. per hour, the marine consumption being sometimes as low as 2 lbs. per I.HP. per hour. The marine engines were, however, under a comparatively constant load, and were not subject to the variations found in colliery work. He thought the surface-labour bill at some collieries could not be further reduced; but he believed it was possible to greatly reduce the fuel bill at all new collieries, and so effect a further reduction in the surface-labour bill. Mr. Benton.

Mr. MAURICE DEACON, referring to the Author's statement that, Mr. Deacon.

Mr. Deacon. by careful attention to the details of the plant, it was possible to reduce the expenditure upon labour at the surface to about one-twelfth of its own cost, thought that he had understated the case, and that he would not have been wrong in estimating the possible saving at as much as 25 per cent. With regard to the placing of workshops on the same level as the pit-banks, he thought that in most cases the disadvantage of such an arrangement would be greater than the advantage. Pit-banks being invariably at a higher level than the surface, this would necessitate the erection of artificial foundations either of masonry, or columns and girders, which, in order to provide the necessary space occupied by the shops themselves and for carrying on the numerous operations which, owing to their magnitude, were generally performed in the open space in front of the shops, would be very costly. The advantages to be gained seemed to be confined by the Author to the facility of transit of material from the shops to the pit, but this could be attained with equal convenience and economy if the shops were on the surface, by means of a landing into the shaft at the surface-level, where heavy material, such as timber, rails, heavy castings, machinery, &c., might be sent down, or by a cage worked from the surface to the pit-bank, by means of a wire rope attached to a small drum on the end of the winding-engine shaft, or to a smaller shaft coupled to it, the circumference of the drum being in the same ratio to the winding-drum as the distance between the surface-level and the pit-bank to the depth of the pit. The cage made one journey between the two levels every time the winding-engine performed a complete wind in the shaft; the same system might be applied to an inclined plane if desired, where a platform carriage on a wide gauge might be used for conveying bulky material to the pit-bank. He thought it was preferable to have the shops on the surface-level for the foregoing reasons as well as for the convenience and economy in having wagon-shops and locomotive sheds near to the fitting shops, where the same engine and shafting might be used, and the workmen be under better supervision.

In the statement of the cost of safety-lamps, the Author omitted the important item of renewals which, in his experience, usually amounted to about ½*d.* per week. A useful addition to a lamp-room was a lamp-testing box, in which the lamps might be tested with ordinary coal-gas before being sent down the mine.

The Author's remark that the size of pit-wagons was generally limited by the height of the seam was correct. It must not, however, be accepted as an invariable rule. At a colliery in

South Wales, under his charge some years ago, in which the seam was 3 feet 6 inches thick, the pit-wagons, which were made of flat bar-iron, carried an average weight of 25 cwt. of coal, and when well loaded as much as 30 cwt., but they were not used for taking into the working faces, the stall roads being only 12 yards apart, and the coal being cast a distance of 6 yards on either side of the road. At an adjoining colliery, working the same seam and the same thickness, wooden wagons were used, carrying an average weight of 10 cwt. of coal. In this case the stall roads were 30 yards apart, and the wagons were taken along the working faces. An important factor in designing a pit-wagon, in addition to the consideration of the thickness of the seam, was the method of working the seam. If it were desired to take them along the faces, their height must necessarily be limited by the thickness of material removed, but not necessarily of the coal alone. In some cases it was found convenient to hole underneath the coal in clunch or fire-clay, or to hole on the top of the coal in shale, batt, or clod, in which case greater height would be made than if the coal alone had been removed. Under such conditions a wagon of greater height than the seam might be used with advantage. He had had experience in working thin seams in Somersetshire, sometimes not more than 18 inches thick, where 9 inches of clunch had been removed from under the coal, but it had been necessary to use wagons of greater height than 2 feet 3 inches. Consequently, they were not taken further than the gate-ends. In South Wales, where large wagons were used, such as before mentioned, the coal was generally worked by the pillar-and-stall method, in which the wagons did not go beyond the gate-ends; but if the coal was worked by the long-wall method, the gate roads were carried much nearer to each other (sometimes not more than 12 yards apart) than was customary in the Midland district, where smaller wagons were used. These different methods of working therefore affected the design of pit-wagons. Mr. Deacon.

The usefulness of balance cages had been confined by the Author to cases where there were two decks on the main cage. The system had been, however, satisfactorily applied to cages with three decks at collieries in Derbyshire. Balance cages might be avoided entirely where two-decked cages were in use by providing two separate banks at the levels of the decks, and two tipplers and screens placed on the same levels as the two decks. The arrangement shown in Fig. 5 for conveying the loaded wagons from the machine to the screens by means of a creeper appeared to him to be unnecessary. The work might be performed equally

Mr. Deacon. well by gravity, and by a creeper for conveying the empties back to the pit-top. In the Table showing the cost of banking 1,000 tons a day there was an item "Two men taking loads out and weighing, 8s." It was not clear whether by this was meant that the weighing of the coal was done by these men, and that no separate weighman was employed, or simply that the two men ran the coal on to the machine and removed it after being weighed by the weighman. He agreed generally with the Author's remarks, but thought that the backward side-tippler might be better arranged by tipping on to a curved shoot brought round the back of the tippler, so that immediately the coal commenced to fall from the wagon it came in contact with the curved shoot, which broke the fall and gradually carried the coal underneath the tippler to the screens. He thoroughly endorsed the Author's statement that the sorting and sizing of coal in a manner suitable to the various markets was of the utmost importance. A coal of comparatively inferior quality, well cleaned and sized, would often obtain a higher price and command a better sale than a coal of greater excellence in quality but less suitably prepared for the market. He also agreed with the Author in his reference to the desirability of providing ample height between the pit-bank and siding-level. It was not an infrequent occurrence to require to increase the number of sizes of coal to be made from a given seam. For instance, a screen might have originally been laid out to make three descriptions only—large, nuts, and slack—and only sufficient height allowed to admit of these three descriptions being made. It might afterwards be found desirable to make pea-nuts out of the slack, or to screen the dust out of the slack, both of which would probably require an additional screen beneath the original screen; and with insufficient height this could not be carried out except by the use of elevators or belts, entailing additional expense and complication, to be avoided if possible. He thought the general statements of the Author as to the superiority of mechanical screens over the fixed-bar screens might be taken as correct with regard to house coals. It was questionable, however, whether, in the case of steam coals, it being only necessary to separate the slack from the coal, the mechanical screen had any advantage over the fixed-bar screen either in the matter of quality or labour cost. If the coal were dirty, a picking-belt or table was indispensable to the thorough cleaning of the coal, unless the number of screens were largely increased. Thus, with one screen and a belt of sufficient length, 1,000 tons a day might be dealt with more efficiently than with six screens without a belt. The

design of headstocks was a matter upon which engineers differed as to the material to be employed. Lattice-girder headstocks were more elegant in appearance, but were nearly double the first cost of pitch-pine. The life of a pit being seldom more than fifty or sixty years, the first cost of timber headstocks, renewed once during the life of the pit, would be found to be cheaper than wrought-iron, taking compound interest into consideration. In the matter of durability doubtless wrought-iron was superior; but well-selected pitch-pine, free from sap, would last for a great many, probably twenty-five to thirty, years, and would answer the purpose as well as wrought-iron. He had found by experience that the principal point of decay was in the mortice-joints, and had recently successfully used cast-iron shoes securely fastened to the timber with strong bolts instead of mortice-joints. If mortice-joints were used, they should be well flashed with lead or zinc, to prevent moisture saturating and rotting the timber. With regard to winding-engines he was of opinion that too little attention had been paid in the past by mining engineers to the economical use of steam. Several types of automatic expansion-gear were now in use, by which fuel might be economised, steam of 80 lbs. to 100 lbs. boiler-pressure being used to the extent of between 15 and 25 per cent. Compound and condensing winding-engines had also been successfully adopted in Lancashire and Yorkshire, and he saw no reason why these should not be more universally adopted by mining engineers. The argument sometimes used that fuel was cheap at collieries had not much weight in the present time of keen competition and necessity for cheap production, when colliery costs were worked out to 0·01 of a penny per ton. Parallel drums and balance-ropes had been advocated by the Author. He was in favour of conical drums, by which the inertia of the load in starting from the pit-bottom was more easily overcome, and less strain was thrown upon the engines and drum. Balance-ropes were a source of considerable economy, but an objection to their use was the introduction of an additional element of danger and complication into the winding-shaft in the event of an accident occurring to the cages or ropes. It was convenient, where it was required, to wind water from the sump by means of a water-barrel fixed to the cage. Mr. Deacon had successfully used balance-ropes for some years at a colliery where the boilers were slightly under power. In this case the ropes had not been carried round pulleys, but had been boxed off in the sump by means of deal battens, to prevent the possibility of the two ropes becoming entangled in case of twisting. The economy of

Mr. Deacon.

Mr. Deacon. fuel might be further effected by the use of very inferior fuel under the influence of forced draught, produced either by fans or steam-jets. He had in use several types of forced-draught apparatus of the steam-jet type, by which the waste dust from coke-ovens and the fine dust screened from slack, and passing through $\frac{1}{4}$-inch square mesh, produced as great an evaporation of water in the boilers as good slack of five times the value; and he had obtained an evaporation of over 500 gallons of water per hour in a Lancashire boiler, 28 feet long and 7 feet diameter, with the refuse from cottage ash-pits.

Mr. Foster. Mr. T. E. FOSTER, of Newcastle-on Tyne, observed that during the last few years a large amount of work had been done in the North of England, for the remodelling of colliery surface-plant and arrangements. Work of this description was generally of a much more tedious and difficult nature than the erection of similar plant on new ground. The machinery had to be arranged and erected so as not to interfere with existing appliances and the change from the old to the new system effected without any stoppage of the work. The economy resulting from the introduction of mechanical screening and the concentration of the banking-out appliances, was, however, so great as to compensate amply for any difficulties resulting from such alterations. The general practice was to screen the coal on end-jigging screens, the coal being subsequently cleaned on picking-belts, although in some instances, generally in the case of gas coals, the process was reversed, the coal being cleaned first and afterwards screened or not as desired. So far as the size of the tub or wagon affected the screen, it was, of course, much easier to separate the coal regularly when it was delivered frequently and in small quantities. The advantages of larger tubs, at any rate in level seams, were so great as to more than compensate for any difficulties which might arise on the screens. In such cases special precautions should be taken to ensure a uniform delivery of the coal on to the screen-head, which was essential to successful working. One of the most useful appliances which had been introduced for this purpose consisted of a short endless belt on to which the coal was tipped. This was placed above the screen and timed to run at a very low speed, so as to deliver the coal in a steady flow.

Referring to results obtained by some of the large and complete plants which had recently been introduced from abroad, the Author had expressed the opinion that not much economy resulted from coal-washing. It must be remembered, however, that the result to which the Author had referred had been obtained after a

comparatively short experience only, and at a time when the coal trade had been hardly in its normal condition. There were times, though seldom, when unwashed coal might be sold with as good results as washed, but the improvement effected by washing often afforded the opportunity for selling coal which would otherwise have had to be put to heap. There were several types of coal-washers which would give sufficiently good results for ordinary purposes at a comparatively trifling first cost and with small depreciation. Mr. Foster.

Mr. GEORGE FOWLER remarked that the concentration of plants which had been advocated by the Author, whilst no doubt tending to economy of labour, was influenced by too many considerations to be advisable in all cases. With reference to sidings, the gravitation system was no doubt by far the best; but his experience on a well-arranged similar system showed that a greater number of shunters was necessary to work a miscellaneous output. Pit-tubs, if they were at all exposed to the weather were better built of wood, with elm sides and larch bottoms. Steel or iron plates increased the weight, and soon wasted away. No comment had been made by the Author on the "sorting-belt," which was in several coalfields one of the greatest improvements of recent date. The business of a colliery manager was not to produce the coal at the smallest possible cost, but to make the largest possible margin between the cost and the selling price. The tipping of everything down over a screen had largely lessened many coal-owners' profits; and in the very numerous coalfields where large, well-dressed coal was practically the only coal which was sold above cost price, the screen pure and simple was entirely out of place. In these cases the sorting-belt, by which the output of the colliery is thinly spread over a continuous band moving before the coal-sorters, had effected considerable reductions in the cost, and improved percentages had increased the relative yield of better coal. The Author's jigger- and bar-screens might usefully deal with the residual coal. Mr. Fowler.

With reference to the hydraulic arrangement which he had invented twenty years ago, he ventured to point to the Author's Table as proving that in some cases it was the most effective adjunct to a large winding-plant. No doubt where a double-decked cage was used in connection with double mouthings and landings, a large weight of coal might be drawn; but where the amount of coal required was greater than a double-decked cage could lift, the three-decker with hydraulic apparatus was as quick in changing the tubs at one level as if three mouthings and three landings were in use. The simplicity of working and the absence

Mr. Fowler. of wear and tear had been established by the results of twenty years of work; and it could be shown that with this arrangement 2,000 tons of coal could be lifted in eight hours from a depth of 600 yards.

Mr. Gillott. Mr. THOMAS GILLOTT remarked that the Author's description of the various items of the surface plant of collieries was naturally restricted to a particular district by reason of the conditions under which the coal of North Staffordshire had to be treated. He believed that it was not uncommon in that district to have as little as 30 per cent. of the seam in the form of large coal, so that when the harder seams of Yorkshire, Derbyshire, and Nottinghamshire coal, with 35 to 15 per cent. of small, had to be dealt with, the arrangements for screening, sorting, &c., at the Whitfield Colliery would not be the most suitable. It was, however, a matter of surprise that no provision was made for taring every empty wagon before loading, as the variation between the painted tares on the various trucks and the actual tares of the same would not average less than 2 cwt. per truck against the colliery owner. In the summer of 1894, his firm's accounts had shown on one particular day the actual weights of sixty-five empty wagons of 8 to 10 tons capacity as being 11 tons 11 cwt. 3 qrs. lighter than indicated by the sum of figures on the trucks, or an average of about 3½ cwt. per truck; and varying between 7 cwt. light and 1½ cwt. heavy. In the plants which he had designed, there were diverging lines above the "empty" weighing machine and below the "loaded" machine, and an intermediate diverging and converging system of lines for loading from screens or belts; and although dead-end sidings were generally objectionable, it rarely happened that the available space would enable them to be dispensed with. But with wagons as now constructed, a gradient of 1 in 80 on good roads was sufficiently steep for gravitation working, and the siding room should be at least double that named by the Author. He considered that no curves on colliery sidings should be sharper than 3 chains radius.

He entirely agreed with the Author's remarks regarding workshops, which at Whitfield appeared to be as suitable as any that could be designed for the purpose of a colliery. If the Author's figures for the cost of oil for safety-lamps were for the average time worked (say, five days per week per lamp) they were high; as for the same number of lamps the cost of the gasoline used by his firm would be about £6 15*s.* 0*d.* instead of £8 8*s.* 0*d.* per week. The cost of driving-power for the lamp-cleaning machinery had not been given, but the expenditure for this item—with a gas-

engine and gas at 2*s*. 3*d*. per 1,000 cubic feet—was 5*s*. 6*d*. per week for gas alone. Mr. Gillott.

He considered that the use of steel-plate bottoms for the tubs was an advantage by reason of their durability and avoidance of the loss of small in transit when wooden bottoms are out of repair. But for the sides and ends timber was preferable; any injury that resulted being generally due to collisions which would injure, almost past speedy repair, a wagon constructed of $\frac{1}{8}$-inch plated sides and ends. And as the tubs holding 10 cwt. need not be heavier than 4½ cwt. there was no advantage on the ground of lightness if the tubs of 12 cwt. capacity weighed 6 cwt. when made of steel. The rapid corrosion in damp or wet pits was a fatal objection to steel bodies.

It was not possible in existing pit-shafts of the diameter usually met with to avoid double or treble decks when four or more tubs have to be drawn at once; but with a 17-foot shaft, four tubs of a capacity of 10 cwt. each could be raised on one deck, as has been done for many years at Messrs. Locke & Co.'s collieries. This pit, working side by side with a lowering arrangement for double decks almost identical with that shown by Figs. 4 and 5, had great advantages over the double-deck working. Sec. 12, par. 1, of the Mines Regulation Act, 1887, had been quoted by the Author with respect to payment of wages by weight, and he might have added that the clause in the case "of stones or substances other than the mineral contracted to be gotten shall be sent out of the mine with the mineral contracted to be gotten... such deductions being determined...between the owner, &c.,... on the one hand...and...check-weigher," had caused more dirt to be sent out than hitherto, and had compelled the adoption of belts for picking and cleaning, besides causing huge heaps of combustible but unsaleable material on the surface. No mention had been made in the Paper of the apparatus in use at many collieries to remove small coal below a certain size for it to be weighed separately, as each tub was tipped and paid for at a different rate to that for large coal.

He considered that all the tipplers shown on Plate 1 would unduly break the coal. Those at St. John's Colliery, Normanton, were driven by power at about 6 revolutions per minute, and were encircled by a spiral plate to allow of the gradual discharge of coal on the elliptic feeding-rollers to maintain a uniform flow over the screens. His experience of the Rigg tippler showed that it was an excellent one if properly used, but no dependence could be placed on the use of the brake for lowering by the men in charge,

Mr. Gillott. and coal was unduly broken when the tippler was carelessly lowered. He was adverse to the use of jigging-screens for large coal to be passed over, and preferred the coal to be first screened on fixed bars or perforated plates after leaving the tub and to remove the dead small, and to be then delivered on a travelling band for hand-picking the lumps, dressing, and sorting coal and dirt; after which the residue of small coal to be separated into marketable sizes on jigging screens.

A disadvantage of creeper-screens was that with their use coal had to fall a long distance, and through the return side of the creeper-chain; by which large thin pieces were often caught and ground into small at the drums. He did not agree with the inclination of 1 in 4 as the maximum for jigging screens, but preferred 1 in 3 with shorter strokes and fewer reciprocations. An eccentric of variable throw was useful for adjusting the stroke to the work.

A head-gear about 50 feet high and of ample strength could not be constructed in timber with less than about 2,000 cubic feet, or in iron with a less weight than 60 or 70 tons. This height of head-gear when of usual proportions was about the limit at which timber can be advantageously used. But the first cost of wrought-iron would be about double that of timber. The space for over-winding was an important matter when high speeds were worked; and although 15 feet to 30 feet might appear excessive, the larger allowance was only about ½ revolution of the drum.

For balancing the load on the engines during winding, his firm had one pair of engines with a wrought-iron conical drum winding from 288 yards deep, and another pair winding 474 yards with a plain drum and balance rope. There were conical drums in use having a maximum diameter of 30 feet and weighing 50 tons, which had cost at least as much as one engine, and were not as good as the plain drum and balance rope. He entirely disagreed, however, with the use of old winding ropes for balancing, as they are too rigid to turn round a pulley about 4 feet diameter, and he preferred specially-made flexible ropes, in which case a return pulley was unnecessary, provided that a narrow rectangular box were placed below the sump-boards to keep the rope from twisting. His experience with briquettes showed that they were commercially a failure in this country, and would be, so long as large coal could be bought at or near its present price. To make a good briquette the smudge should be washed for the removal of dirt, and the difficulty and expense of drying the washed material was serious. Less than 10 per cent. of pitch was rarely used, and the

cost being 30s. or 35s. per ton it was not easy to produce briquettes that would command a saleable price in inland towns. Doubtless it was a matter for grave concern that so much small coal should be wasted, either underground or on the surface; and it was also a matter of anxiety to colliery owners that the relative amount of slack made during the last twenty years had in some districts increased considerably. Mr. Gillott.

Mr. W. S. GRESLEY, in drawing a comparison between American and British practice regarding colliery surface-works, observed that the much larger pit-wagons used in American collieries, no matter what the thickness or inclination of the seam might be, perhaps made the methods of dealing with them on the surface very different from those customary in Great Britain. Pit-wagons with capacities of between $1\frac{1}{2}$ ton and 2 tons were quite common, even in the bituminous coal regions, and in $3\frac{1}{2}$-foot long-wall workings a 1-ton wagon was considered a small one. The gauges of the mine-tracks were very wide, as the wheels were always on the outside of the wagon. The wheels themselves were much larger than those used in England, and shorter wheel-bases were employed. Brakes were of course often necessary in cases in which gradients of over 3 per cent. or 4 per cent. occurred. More than one wagon at a time was never hoisted in the cage, but outputs of over 2,000 tons in ten hours were in some cases attained. The depth of the shafts was about 350 feet in these instances. The height of the pulley-wheels on head-gear above the cage-chains when the cage was at the surface seldom exceeded 5 feet or 6 feet in America. He had introduced the King-Humble safety-hooks at shafts in Illinois with good results, but in order to use them it had been necessary to raise the pulleys about 2 feet. It was exceptional in America that a winding-engine man could see the pit-top, for the reason that the heapsteads were always boarded up as a protection from the weather. High-pressure steam, between 75 lbs. and 90 lbs. per square inch, was always used; and in a few cases very high speeds of the cages were employed, so high, that in one case within his knowledge, when the cage approached the top of the hoist, which was 120 feet higher than the surface or ground-level, and its velocity was checked, the slack, or small fragments of coal, might be seen flying upwards off the wagons, on account of the sudden reduction of the speed of winding. All pit-wagons were, in America, built with a door at one end; and in the Western States, in shafts about 100 feet or 120 feet in depth, automatic dumping-cages, the wagon being emptied down a shoot or on to a screen without leaving the cage, were very Mr. Gresley.

Mr. Gresley. common. The method was applied in a variety of ways. In cases where self-acting dumping-cages were used, all the coal was emptied on one side of the shaft, and the rubbish or rock on the opposite side, a simple movement of a lever by the man in charge at the surface causing the cage to tilt to whichever side it was required. At modern collieries in the Anthracite region it was customary, in the case of shafts or slopes, to haul the pit-wagons by locomotives from the top of the slope or shaft over the surface to the "breaker," where they were further hoisted by machinery to the top of the breaker. At one colliery in that region, however, the product of the mine was hoisted through a steel head-frame 180 feet high, and the coal was shot down an inclined plane from self-tipping cages to the "breaker," about 200 feet away, this distance being necessary because the State Mine Law prohibited breakers being built nearer to the shafts. Head-gear and buildings in which coal—both anthracite and bituminous—was screened and otherwise prepared for the market, were often constructed of steel, which cost about one-third more than timber. West of the Alleghany Mountains, colliers were paid only for the coal that passed over the screen-bars, the area of the screens being fixed by law; but the width between the bars varied in different districts between $\frac{3}{4}$ inch and $1\frac{1}{2}$ inch. In the Connellsville coke region, however, where the coal was exceptionally soft and easily worked, the product was not weighed until it had been coked, and the miner was paid by the wagon-load, at the rate of about 25 cents per ton.

Prof. Koehler. Professor G. Koehler, of Clausthal, considered that the Author's description of colliery surface-works in North Staffordshire gave a good idea of what had been done in the way of mechanical appliances. It was, however, easy to carry the employment of such appliances too far, especially if they were not simple in construction, and if they were liable to rapid wear. In such cases frequent repairs could appreciably interfere with the output. This drawback appeared, however, to have been successfully obviated in the appliances under discussion, both in the automatic movement of the full and empty wagons by suitable inclination of the rails, and in the movement of the wagons from the shaft to the weighing machine, thence to the tippler, and back again to the shaft. The same remark applied to the equipment of the cages with two or more decks. The Author's remarks as to the advantage of steel wagons over those of wood appeared to be quite accurate, especially if the steel plates were fastened by short screws and not riveted. Further, the view that wagons should

not be too large and heavy, was in the interest of the greatest possible output undoubtedly worthy of support. The proposal to balance the centrifugal action of rotary-plane screens without the employment of counter-weights, by combining two such screens which balanced each other, was both new and interesting. Prof. Koehler.

Mr. CHARLES LEDOUX, of Paris, observed that the surface-arrangements in North Staffordshire, as described by the Author, did not differ notably from those in use in analogous cases in the north of France, in Belgium, or in Westphalia. It was advantageous to arrange the sidings with a sufficient slope for the empty wagons to easily descend to the screens and from these to the loaded trains. A side line allowed of the locomotive returning the empty wagons to the sidings. These arrangements had, for a long time, been in use in the large collieries of the north of France, of Belgium, and of Westphalia. Mr. Ledoux.

Reference had been made by the Author to the size and weight of pit-wagons, and to the use of iron and steel instead of wood for their construction. In the north of France and in Germany metallic wagons were preferred and were being more and more largely used. Rivets were used for those of sheet iron. In the north of France the wagons were generally lighter than those described in the Paper. At Anzin they weighed between 484 lbs. and 495 lbs., and the mean weight of coal carried in them was 990 lbs. The relation between the useful and the dead weight was therefore about the same as that of the wagons used in North Staffordshire. It was certainly possible, by the improvement of the screening arrangements and by the proper setting out of sidings, to increase the useful effect of the men and horses by between 25 per cent. and 30 per cent. Regarding the number of decks in the cages, the type of cage used in modern installations in France, Belgium or Germany, had two decks carrying four wagons upon each, or eight in all. A total output of 120 tons per hour was given by this arrangement, which, however, required a diameter of 26½ feet for the shafts. Stops, operated by hydraulic power, were furnished at the bottom of the shaft, and allowed of the cage at the surface being worked independently of that at the bottom of the shaft. At the bank the cage was caused to descend by the action of the engine and to discharge each deck successively at the same level. The operation was much facilitated by the stops, which avoided the necessity of raising the cage before its descent. Great rapidity was, in this way, secured, with the additional advantage of having but one level for landing. With the hydraulic system of landing, described by the Author, quickness

Mr. Ledoux. might be secured, but one or two receivers were necessary for each deck, so that a greater number of men was necessary than if but one landing level were used. The head-gear which was now erected in France, Belgium and Germany was always metallic and of lattice or round girders. The height of 50 feet which had been stated by the Author was usually there exceeded, and was in general between 65 feet and 80 feet, but in Westphalia it sometimes reached 100 feet. The rule imposed by the German authorities was that the free space between the pulley and the attachment of the cable to the cage resting on the stops must be at least equal to the length corresponding to one half-turn of the engine. This height was, however, a minimum, and a greater was to be preferred. In France and in Belgium flat cables of aloe-fibre, iron or steel were chiefly used. The aloe-fibre cable was preferred in Belgium, but in France the tendency was rather towards the use of metallic than of vegetable-fibre cables. With the latter sufficient regulation of the moments was obtained, but with the flat metallic cables there were great differences between the moments at departure and arrival, and it often happened that there was a negative moment during a considerable part of the run, the system giving out work under a closed regulator.

Spiral drums and the Koepe system were but little used in France. They were, on the other hand, almost exclusively employed in Westphalia, and the round cables were found to have great advantages over the flat. To the Koepe system there were many important objections, of which the chief was that in case of the rupture of the ascending cable the whole balancing system fell into the shaft. The danger was in part avoided by replacing the Koepe pulley by two cylindric drums, and the single cable by two, one winding upon each of the drums; but the difficulty arising from possible rupture of the cable, and others besides, remained. Another method of balancing was in use in Hansa Colliery, at which the depth was 2,740 feet. The stranded-steel cable was round, 1·97 inch in diameter, and weighed 19·2 lbs. per yard. The daily output was 700 tons. The drum was 30·4 feet in diameter and 13·7 feet in width. Compensation was effected by means of a disused cable passing up and down the shaft behind the guides, and at the bottom of the shaft round pulleys. The cable was carried by a smaller one, between $\frac{3}{4}$ inch and 1 inch in diameter, which was passed one half-turn round the drum, and followed the motion of the system, the joints between the two cables being at the levels of the two cages. The pulleys in the bottom of the shaft, and the falling of the cable into the pit in case of

rupture, presented, however, objections to this system. A modification of it had been designed and used at Monopol Colliery, in which the smaller cable supporting the compensation-cable coiled upon the main drum, and occupied upon it the place of the main cable, as it uncoiled, and *vice versâ*. Mr. Ledoux.

The weights were as follows:—

	Lbs.
Cage	46,200
Eight empty wagons	55,000
Coal	96,800
Total	198,000

	Lbs. per Yard.
Compensation cable (flat, and of iron)	17·2
Smaller cable (round, 0·95 inch diameter, and of steel)	4·44

The waste in colliery engines had rightly been emphasized by the Author. It was now customary to cut-off at about four-fifths of the stroke. He had made the following observations on winding-engines working at an effective pressure of 50 lbs. per square inch:—

Type of Engine.	Work indicated per lb. of Steam.	Useful Work per lb. of Steam.	Consumption of Steam per Ton raised 100 Feet.	Heating-Surface per Ton raised 100 Feet per Hour.
	Foot-lbs.	Foot-lbs.	Lbs.	Square Feet.
Engine with full admission and normal slide-valve	20·34	14·76	15·05	6·27
Engine with admission for four-fifths of the stroke	34·77	25·26	8·803	3·63
Engine with variable expansion-gear	59·37	43·00	5·174	2·11

The use of variable expansion-gear was becoming more and more general in France as in England. That controlled by the driver had been mentioned by the Author as being preferable; but it was found that greater efficiency was obtained by the use of expansion-gear controlled from the regulator, and not operated by the driver, who could then vary the speed by means of the main valve alone. Cylindric-valves, or pawls in the slide-valve systems, could be used for this purpose.

Reference had been made by the Author to the manufacture of coke from non-bituminous coal in which the production had not amounted to 50 per cent. This did not appear to be profitable working, even if the coke had been of good quality; but he thought a better result would have been obtained if coal having

Mr. Ledoux. between 10 and 13 per cent. of volatile matter had been used, instead of culm containing as much as 40 per cent. Coal having between 35 and 40 per cent. of volatile matter was not suitable for the manufacture of coke, and the agglomeration process was found to be better adapted to its use. In Belgium and in Westphalia the anthracitic dust was treated by mixing it, after a final grinding, with rich coal having about 25 per cent. of volatile matter. A hard product was thus obtained which behaved very well in the fire, but which commercially had not been very satisfactory on account of the grains of anthracite remaining black in the midst of the grey mass of coke. The duration of the baking depended upon the amount of volatile matter to be expelled and burnt, but with 15 or 16 per cent., but twelve hours would be required in some ovens. The very long period of twenty-four hours or more was usually required, however, in the ovens, which should be very close. It appeared that the best means of using the culm was by direct combustion on the grate with a mixture of bituminous coal-dust, and by the ordinary briquette-making processes, which in France did not differ notably from those described in the Paper.

Mr. Marley. Mr. J. W. MARLEY thought there was no doubt as to the great importance, for successful colliery management, of well-laid-out surface arrangements. The Author had referred chiefly to the remodelling of an existing establishment, with its attendant difficulties, which he had successfully overcome, as he had seen when he visited Whitfield Colliery about two years ago. Such a remodelling was more difficult than the design for a new plant. He thought the railway arrangements at Whitfield were good, though perhaps 1 in 30 could scarcely be alluded to as a "gentle descent to the screens." It was always well to avoid locomotive work through the screens, and to allow a separate road for the loading of each class of coal. The Author had rightly noticed the consideration of the quantity of coal in a pit-wagon as affecting the screening arrangements where much small was made; and 10 cwt. of coal was sufficient to put on at one time, although he believed pit-wagons carrying more were in successful use with vibrating screens. He considered the side-tippler the best. In speaking of the height of the heapstead for screening, the Author had omitted to mention the consideration due to the height of the railway wagons. On some railways higher wagons were in use than on others. He was of opinion that the vibrating- or jigging-screen had now shown complete superiority over every other method, and certainly it was much better than the old fixed-bar

screen. Picking- or cleaning-belts were of great importance at some collieries. A good height should be provided for the head-gear. Mr. Marley.

Prof. E. Treptow, of Freiberg, referred to some of the newer appliances which had been found satisfactory in Germany. For shunting railway wagons endless ropes working between the rails had been largely adopted. The clips employed at the Zwickau-Oberhohndorf collieries in Saxony were of special construction. As they had already been in use for about two years with satisfactory results, their construction, which was recently described in the journal *Glückauf* of Essen, might be of general interest. The jaws of the clip were comparatively broad, so that a considerable portion of the rope was gripped. The lining was wedge-shaped and not fixed in the clip, but was movable in dovetailed grooves in the direction of the rope, the amount of movement being limited by a set-screw. For throwing the clips into gear, with three full or nine empty wagons at a time, a hand-lever and screw were employed. As soon as the jaws pressed against the rope they were carried forward by it, when, owing to their wedge-shape, the grip on the rope automatically tightened. The tippler preferred on the Continent was that of Karlik, as by it the discharge of the coal on to the screens was effected gradually, so that the screens were not inordinately loaded. The process of unloading and returning the empty wagon was thus performed with rapidity. The gradual motion was obtained by the employment of two friction-wheels running at different speeds and imparting motion to the tippler through flat-rail segments. After the tippler had made a complete revolution, the friction-wheels were automatically thrown out of gear, and the wagons pushed through in the ordinary manner. Where large quantities of coal had to be screened rotary-plane screens were now coming into general use in Belgium, Germany and Austria, as they presented the great advantage of causing a minimum breakage of the coal. The three best-known forms of these were the Karlik, Klönne, and Coxe screens.[1] Of these the Karlik pendulum screen appeared to be the most efficient. For loading the screened coal into the wagons the well-known Cornet belt was largely used.[2] Prof. Treptow

Mr. B. Woodworth observed that for the economical working of colliery winding-engines the work to be done in lifting the loads should be arranged to be as equable as possible, so that the engines might be run under steam as far as possible for every lift. As Mr. Woodworth.

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[1] Minutes of Proceedings Inst. C.E., vol. cxvi. pp. 13–16.

[2] See Lamprecht, "Die Kohlenaufbereitung," Leipsic, 1888, Plate X.

Mr. Woodworth. good a paying load as was found to be practicable should be brought up, and the whole of the tubs should be simultaneously landed and hooked on, so the necessity of moving the cages while doing it might be avoided. He would recommend the adoption of a run of between 24 and 36 revolutions per lift, as might best suit the practical conveniences of the work in each individual case, and the use of what was considered fairly high pressure of steam, say between 80 and 120 lbs. per square inch. If practicable, the compound system, with separate condensing arrangements and fixed or variable expansion-gear connected with the high-pressure cylinders, should be used. In all cases in which the simple Koepe balance-rope system was not practicable, and that was so in most cases, he would use two fast ropes on a nearly parallel drum, with separate grooves to hold the spare rope laps, and a groove at the centre or side of the drum specially prepared for the use of a separate balance-rope arrangement, thus leaving the winding-ropes and cages as free as in the ordinary system, and keeping the turn-pulleys and frames for balance-rope perfectly clear of the sump in all cases.

Fig. 20.

He suggested a section of drum shrouding and barrel, *Fig. 20*, for a central separate balance-rope in which the diameter at A and A_1 was 2 inches or 4 inches less than the diameter at B and B_1, and which had spaces at C and C_1 to receive the spare laps of rope, the inner rib being spiral and having a gap for the rope to pass through from C to A for the winding portion. This arrangement would give facility for adjustment in slight irregularity of winding, as by simply lifting a lap out of C on the side that ran slower it would increase the lap in proportion to the difference between A and B, and avoid an excess of slack rope to be dealt with at the landing-points. This system of balance-rope working would be applicable to cases of winding from equal or unequal depths in one shaft with two ropes, or from two shafts with one rope in each, provided there was room in one for the balance-ropes and gear, and it was also practicable for winding with either round or flat ropes. In cases in which a spare shaft was in line with the engines, the balance arrangements could be worked entirely clear of the winding-shafts. When well-proportioned, the load was practically equal throughout the lift, consequently the full speed was attained in a minimum number of revolutions, and

could be maintained until within a shorter distance of the top than would be safe or advisable in the ordinary way of winding, so the engines could run under steam further, saving considerable time and avoiding the need for use of excessive brake-power, and its consequent waste of useful effect. For economy and efficient working he would suggest that the engines took full steam, about 85 per cent. admission, for 12½ per cent. to 15 per cent. of the lift, and that then an expansion-gear arrangement automatically came into operation, cutting off the steam-admission at between 25 per cent. and 40 per cent. of the stroke for the remainder of the run according to the power required. This gear would act in full work, probably for between 70 per cent. and 75 per cent. of the lift, leaving but a small portion to be run without steam up to the landing; and in cases in which good condensing arrangements were available, he would use the tandem compound-engine. In designing any arrangements of this kind, the question of lifting the gross load of cage, tubs, and coals, for the space of slack rope used at landing, must not be overlooked; and if the engines, when taking full steam, were not capable of picking up this maximum unbalanced load, there would then be required a special landing arrangement to suit the case. Mr. Woodworth.

Particular care should be taken that the tubs and cages were not heavier than necessary, as for landing purposes these could not be balanced in any way whatever, although the ropes could be balanced in all cases; and when it became a question of drawing more than two decks or platforms to the cage, it should be considered whether three decks be adopted to simultaneously land all the wagons, or to lay out for drawing four decks and landing the first and third simultaneously, then changing positions so as to land the second and fourth decks simultaneously, as the latter arrangements gave plenty of head-room between the landing-platforms, while still enabling the cages to be kept within reasonable height, and also reduced the number of balance-lifts or elevators necessary to bring the coals to one level for being dealt with at the screens, as is usually found necessary.

Mr. Wain. Mr. Wain, in reply to the correspondence, said that although he knew cases where the quantity of coal consumed actually amounted to 10 per cent. of the output, as had been mentioned by Mr. Benton, such were altogether exceptional, and he believed that 5 per cent. was a fair average. He thought that the best modern practice would not show less than 4 per cent. to 4½ per cent. for collieries working seams at any considerable depth from the surface. A saving of 1 per cent. on an output of 500,000 tons

Mr. Wain. per annum, taking the value of the fuel used as low as 2*s.* 6*d.* per ton at the pit, was equal to a 7½ per cent. return on an expenditure of £10,000; and there could be no doubt that heavy expenditure to secure economy in fuel would be as advantageous to colliery-owners as to any other users of steam.

Attention had been directed by Mr. Benton to the high temperature of the waste gases from the boiler-flues, and there were few cases which did not admit of this being used with advantage for feed-water heating with the Green or other similar types of economizer. It was true that the water available for boilers at collieries was often of an unsuitable quality; and, unless the same care was shown in cleaning the scale from the pipes of the economizer, as was usually taken with the boilers themselves, there would be trouble and expense in maintaining economizers fixed in the flues. Still, with moderate care, good results were obtained, and he knew that a saving of as much as 20 per cent. on the quantity of fuel used, or 1 per cent. on the output, had been effected by the application of Green economizers to such boilers. In fixing these appliances, however, it must be remembered that the absorption of a large part of the waste heat would affect the chimney-draught, and either forced-draught or increased height of the chimneys would be required. He believed that although the forced-draught appliances spoken of by Mr. Deacon were of great value where the chimney draught was insufficient, or for burning coke or other matter containing a low percentage of volatile hydro-carbon, the best and most economical rule in colliery work was the well-known plan of providing a chimney high enough to give sufficient draught without fans or blowers. He gave the following particulars of Green flue-economizers working with a battery of eleven 30-foot × 7-foot Lancashire boilers, about forty pipes 9 feet long × 4 inches in diameter being fixed to each boiler. The figures given were not the result of special tests to determine the efficiency of a particular apparatus, but were based on continuous operation in colliery work.

—	Temperature.	
	Feed-Water.	Waste Gases.
	°F.	°F.
Entering economizer . . .	110	820
Leaving ,, . . .	225	470
	Increase 115	Decrease 350

The feed-water passed to the economizer through an exhaust injector, driven from the fan-engine, and was heated to 110° before reaching the economizer pipes. The chimney was 225 feet high, of 8 feet internal diameter at the top, and gave a draught equal to $1\frac{3}{4}$ inch on the water-gauge. Mr. Wain.

The position of the workshops in relation to the pit-banks would of course depend largely on the surface contour; but where the elevation at the pit-head for screening had to be obtained by means of a platform supported on girders or pillars, it was an easy matter to construct a landing at the railway level for heavy material which had to be sent down the pit. It was open to question whether the pit-banks supported on iron pillars, as was the usual modern practice, were preferable to the more substantial structures obtained by building strong rubble retaining-walls, the materials for which were generally to be obtained from the pit-shaft, the intervening spaces being filled up with other spoil from the sinking. In the former case, the head-gear had to be made much stronger, as the supports would be generally 20 feet longer than when erected on pillars; and, in order to make a thoroughly substantial erection to resist the vibration and shocks attending the work, very heavy expenditure would be required. One serious objection to having the pit open to the railway level of the screen-sidings, was the difficulty of preventing the fine dust from the screens from being carried in the air down the shaft into the underground workings. In the case of dusty coals, that was a matter of considerable importance; and as an instance of the large quantities of fine dust deposited in the neighbourhood of screens, he mentioned a case where, during the coal strike of 1893, he fired six 30-foot Lancashire boilers to provide steam for pumping and ventilating purposes for two weeks with fuel obtained by cleaning up the deposits of coal-dust in the screen sidings illustrated in Fig. 1, Plate 4. There was one advantage possessed by pit-banks supported on pillars and girders, which could not be overlooked; and that was the convenience they afforded for the storage of timber and other material under cover and near to the shaft.

The cost of working safety-lamps given in the Paper included all charges for repairs and maintenance, except such as were caused by careless handling on the part of the miners, for which they were charged. The cost for lamp-oil might be reduced by using petroleum-spirit ("colzaline") or petroleum. There had been some prejudice against the introduction of such highly inflammable substances into underground workings; but recent

Mr. Wain. trials had proved that, with properly constructed burners, petroleum of good quality might be substituted for the mixed colza oil at about one-third of its cost.

With regard to the size of pit-wagons, that was often influenced by local circumstances; but, in any case, the dimensions should be such as would allow the loading to be done in the working face and not at the road end, so as to save breakage of the coal.

The cost of banking out had been referred to by Mr. Deacon. The item of cost for taking the wagons out of the cage and weighing them was for passing the trams over the weighing-machine, and did not include the wages of the weighing-clerk.

Some pertinent remarks had been made by Mr. Fowler as to the provision of picking-belts. These were especially necessary in many districts, and particularly in the Derbyshire and Nottingham coalfields, where the belts were used not so much for the purpose of removing foreign matter as for sorting the coal into different qualities. In those districts the same seams often contained soft house-coal and the hardest steam- or blast-furnace fuel, with various intermediate qualities; and it was not uncommon to make ten or more qualities or sizes from one seam. Under such circumstances, it was impossible to overstate the value of suitable picking-apparatus. The subject of coal-sorting appliances was, however, too large to be properly dealt with in a general Paper on surface-works. It would be well if every one interested in colliery-work would lay to heart the words of Mr. Fowler, that "the business of a colliery manager was not to produce the coal at the smallest possible cost, but to make the largest possible margin between the cost and the selling-price." In many cases where the utmost economy and most convenient arrangements would only effect a slight saving, it might be possible by careful selection and preparation of the coal for market to largely increase the average selling-price.

He was afraid that he had not explained the hydraulic banking arrangement sufficiently in detail; otherwise, Mr. Ledoux would not have assumed that a larger number of men was required than with a single landing. In practice, the operations were extremely simple and almost automatic, no men being needed to receive the loaded wagons from the upper decks, and the movement of the cages being controlled by one man in a small cabin near the pit-top with a series of suitable valves.

The systems of balancing used at the Hansa Colliery and that described by Mr. Woodworth appeared to be practically the same, and would offer facilities for balancing when it was required to

lower the cage into the sump for winding water, in which case an ordinary balance-rope would be impracticable. Mr. Wain.

It had been suggested that the gradients of the railways and tramways were too steep, but in practice it was found that allowance must be made for wagons which did not run freely, and particularly for frost and snow. The empty railway-wagons were easily controlled by the brakes; and to regulate the speed of the trams on the gravity roads at the pit-bank, light springs, fixed on the side of the rails, served to check the speed when it became excessive. These could be removed in bad weather if the trams did not run well.

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18 December, 1894.

SIR ROBERT RAWLINSON, President,
in the Chair.

The discussion on the Paper upon "Colliery Surface-Works" by Mr. E. B. Wain occupied the evening.

"Estuaries."

By Henri Léon Partiot, Inspecteur Général des Ponts et Chaussées (France).

Reply of the Author to the Correspondence.[1]

Mr. Partiot. Mr. H. L. Partiot,[2] in reply to the correspondence, observed that it was desirable to define the meaning of the term "neck," for Mr. Shoolbred had said that "the contraction of the Seine between Tancarville and Quillebeuf had quite as marked, and a similar effect upon the tidal flow in that river, as the one between Royan and Pointe de Grave had upon that of the Gironde." The Pointe de Grave, however, which projected like a groyne towards the opposite shore, reduced the width of the Gironde to 3 miles, which amounted to 6½ miles at Richard and down to within a very short distance above the Point. On the Seine, on the contrary, Tancarville was 3 miles below Quillebeuf; and previously to the training-works, the opposite bank was 2½ miles from Tancarville, and about 1½ mile from Quillebeuf; and the estuary from Havre to near Aizier appeared to him distinctly trumpet-shaped. The two estuaries acted in a totally different manner. He considered that an estuary had a neck when the two banks formed a decided contraction opposite, or nearly opposite one another, as on the Gironde, with a great enlargement in width above and below. This neck might be long, as on the Tagus below Lisbon, or short, as at the Pointe de Grave and on the Foyle. This definition would exclude rivers with trumpet-shaped mouths flowing into bays. He thought that the explanations he had given in his Paper concerning estuaries with necks would meet some of the objections raised in the correspondence. The depth in a neck depended on its width, and the quantity of water flowing through it. When the tides were small, or the neck too wide, the depth

[1] Minutes of Proceedings Inst. C.E., vol. cxviii. p. 103.

[2] Want of space has obliged the Editor to curtail this reply, which is an abridged translation of the MS. furnished by Mr. Partiot. The French original may be consulted at the Institution by any person desiring fuller details.—Sec. Inst. C.E.

was less, and the lengths of the resulting channels below and above the neck were consequently shorter; and therefore it was not surprising that necks, either natural, or formed by training-walls, might have an insufficient depth, and form short and shallow channels. By deepening the neck, the channels formed by it would be deepened, and the bar below the neck would be lowered; and it was with the object of thus lowering the bar of the Loire that he had proposed to rectify and contract the oblique neck which separated St. Nazaire from Mindin Point, as referred to by Mr. Vernon-Harcourt in the discussion. The effect, however, of the neck on the bar would be reduced if secondary channels came into the main channel between the neck and the bar; and therefore it would be advantageous to close these secondary channels, in order to extend the influence of the neck and the principal channel. Consequently it might be advisable to close the minor channels which opened on the left bank into the main channel of the Mersey below the neck. His theory was independent of the length of the neck, as proved by the case of the Tagus; and the bar might therefore be brought under the influence of the neck, and lowered, by prolonging the neck seawards by means of jetties. Mr. Partiot.

It was considered by Professor Gaudard that it would be better to make some of the flood-tide enter the Seine estuary over a low breakwater connecting Ratier and Amfard, in order that the water might come in less charged with sediment than at present; but he (Mr. Partiot) was of opinion that the tidal water might be admitted through the neck itself, as occurred in nature in the estuaries he had cited, which had existed since the earliest times without their being silted up. The tide carried out as much silt as it brought in, and more when aided by the fresh-water discharge of a river, as evidenced by the estuary of the Gironde, which had existed for centuries in spite of the materials brought down by the Garonne and the Dordogne. In Professor Gaudard's project for the Seine, the Villerville channel would admit a current fully charged with silty sand from the coasts of Calvados, nearly the sole source of the deposits which encumbered the estuary; and the navigation by this outlet would be impeded by the banks of Trouville and the Seine. It would be much better to close this outlet, and to admit, as far as possible, only the clear waters of the Antifer current into the estuary. Mr. Shoolbred had been imperfectly informed as to the proposals for securing the approaches to Havre, and the completion of the Seine training-works, which had not yet been passed by the Senate and must return to the Chamber of Deputies. The silting-up, however, which always had occurred in front of Havre

Mr. Partiot. when the navigable channel of the Seine remained in the centre, or at the south of the estuary, showed that the execution of the scheme of training-works approved by Mr. Shoolbred would result in the accretion of the foreshore in front of Havre, behind the north training-wall; and even if the opening up of the Port of Rouen for the largest vessels should render the formation of the proposed new works on this site unnecessary, it would be essential to create and maintain a great depth in front of the existing entrance to Havre; and therefore he could not support the scheme referred to by Mr. Shoolbred.

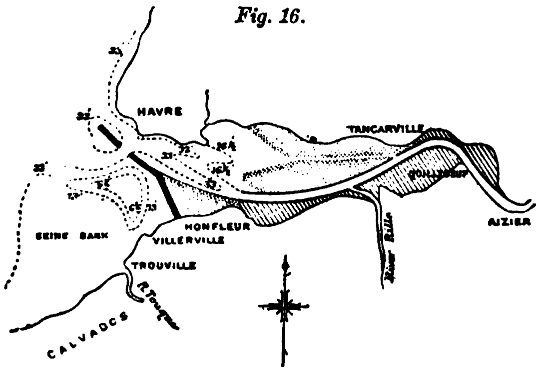
When he had had charge, as engineer, of the works at the outlet of the Seine for four years, in 1857, the training-walls being nearly finished down to Tancarville and La Roque, he had to present a scheme for the extension of the training-walls, in compliance with the request of the town of Rouen, which desired their prolongation down to Honfleur. He, however, soon recognised that the fears of silting-up manifested at Havre would be well founded if this project was carried out, and that the entrance of the Seine should be fixed close to the jetties of this port. For that, it would suffice to prolong the left training-wall, transforming it into a breakwater carried out in front of Havre, in this way converting the estuary into a great sluicing-basin which would deepen the approach to the port. The estuaries of Arcachon and the Gironde showed that great depths would be obtained in front of Havre; that channels would be scoured out above and below, on the one side towards the trained river, and on the other side towards the deep sea near Havre; and that the Seine estuary, being converted into an estuary with a neck, would be maintained like this class of estuary. This was the basis of his project of 1859. Subsequently, for the sake of economy, and in order to increase the area of the enclosed estuary, the length of the breakwater was reduced by making it start from Villerville, thereby constituting it a Pointe de Grave at the mouth of the Seine. He had also designed a low training-wall along the left bank, to direct the current from Honfleur to the breakwater; and he had recently added a little branch channel going from the Seine near Tancarville through the northern part of the estuary, *Fig. 1.* The essential portion of the scheme, however, consisting in closing the southern and central channels, and making all the discharge of the Seine and estuary go through the northern channel close to the jetties of Havre, had been kept unaltered. It was necessary at the outset to determine the requisite widths between the training-walls below Tancarville, which depended on the discharge of the river

at the various points and the desired depth, which he had arrived Mr. Partiot. at by the methods he had indicated in 1861, and had developed in 1892.[1] The width of the river was at present 1,480 feet at Quillebeuf, and 2,300 feet at Tancarville; and adopting the widths proposed by the engineers of the Seine for the trained channel, of 3,940 feet at the mouth of the river Rille, and 4,600 feet opposite Honfleur, he had calculated that, with an average velocity of 3 feet per second, these widths would give depths of 10½, and 18¾ feet below zero respectively at these places. As he considered it expedient that, in order to provide a roadstead for the largest vessels, a depth of 34½ feet below low-water of spring-tides should be afforded half-way between Honfleur and Havre, a depth of 46 feet was required in the channel near Havre, equivalent to that of the pass by which the flood-tide from the north entered the estuary in the neighbourhood of Havre. Assuming that the Seine was trained down to Havre, and adopting a mean velocity of 3¼ feet per second, equal to the flood-tide current in the Gironde at the Pointe de Grave, he had found that the width of the Seine at Havre should be 2,810 feet. The corresponding sections at the mouth of the Rille, Honfleur, and Havre respectively, would be 10,436, 14,857, and 17,344 square yards, and the discharges of the flood-tide at the same points, 271,392, and 505 million cubic yards respectively. The Seine thus trained down to Havre would, accordingly, furnish increasing sections below Tancarville; its outlet would directly face the tidal wave, and the clear current coming from Cape Antifer; and it would be placed as far as possible from the Calvados coast, the source of almost all the deposit in the estuary. This scheme, therefore, he thought ought to satisfy those who desired to have trumpet-shaped outlets. A depth of 10½ feet below zero, above the mouth of the Rille, would afford depths at high-water, of 36¼ feet at springs, and 30¾ feet at neaps; and these depths would be maintained by the action of the currents alone, without dredging. Even if the estuary of the Seine was to be entirely silted up, the river might still be brought into the condition described; and the project offered perfect security in respect to it. The estuary, however, would not silt up; and new and important advantages could be derived from it. To facilitate the maintenance of the estuary, he proposed to reduce the width of the Seine a little at the mouth of the Rille and Tancar-

[1] "Étude sur le mouvement des Marées dans la partie maritime des Fleuves, 1861," and "Étude sur les Rivières à Marée et les Estuaires, 1892." H. L. Partiot.

Mr. Partiot. ville, and to form an opening near the latter place, 262 feet wide, with its sill $3\frac{1}{4}$ feet below low-water, thereby creating a false branch, which by its probable wanderings would undermine and keep down the level of the banks in the estuary, or if it maintained its direction, would produce the effects mentioned by Mr. Stoney with reference to the proposed training-works in the Mersey, namely, the lowering of the estuary for considerable distances on each side; and the sand stirred up by the tides and waves would descend into the false branch, and be carried away seawards, *Fig. 16*. The volume of water retained at spring-tides in the portion of the estuary to the north of the training-wall on the right bank, had been estimated from the chart of 1880 at 720,000,000 cubic yards; and adding to this the flow in the main channel during flood-tide given above, it appeared that 1,225,000,000 cubic yards should

Fig. 16.



Mr. Partiot's Scheme for the Seine, showing Anticipated Results.

pass in through the neck during the flood, which, with an average velocity of $3\frac{1}{4}$ feet per second and six hours fifty-nine minutes' duration of flow, would require a section of 44,764 square yards below mean sea-level at Havre, and a total width of 6,850 feet. In this estuary with a neck there would be two channels, one going into the main channel and the other towards Tancarville; and the channels would have a great depth near Havre, and would form a roadstead to the south and close to the port. A channel 2,300 feet wide and 33 feet deep would be made, giving Havre an outlet to the north through the little roadstead, which would be protected by a prolongation of the breakwater over the shoals of this roadstead; and an opening would be left in the breakwater to the south-west of the Havre entrance, 3,937 feet wide, in the neighbourhood of depths of 46 feet in the Amfard channel, so that

Havre would be accessible at all times by channels at least 33 feet deep, *Fig. 16*. He had not taken into account the 114,000,000 cubic yards of water which covered the triangular area between the breakwater and Honfleur at spring-tides (which area would be kept low near the low training-wall by the effects alluded to by Mr. Stoney), because accretions had taken place since his calculations of the tidal capacity of the estuary had been made, and further accretions might occur before the completion of the works. The formation of a triangular bank on the left shore, similar to Tuns bank at the mouth of the Foyle, Fig. 15, Plate 4, must be anticipated. The meeting of the two tidal waves from the north and east in the Bay of the Seine, maintaining high water at Havre and along the Calvados coast, was a wide-spread tidal phenomenon which could not be much affected by the closure of the two passes of the Seine; but it was probable that a portion of the Calvados wave, entering the bay along the coast towards Honfleur, would reach Havre earlier and prolong somewhat the period of high-water. This scheme, affording a depth of over 30 feet at high-water of neap-tides up to Rouen, a sheltered roadstead for the largest vessels near Havre, and two approach channels with depths of 33 feet at low tide rendering Havre accessible at all times, would cost £4,000,000, which would be promptly repaid by the saving effected in the cost of transport. These results explained why he could not accept the projects prepared by the Commission of 1885, or subsequently under its inspiration. Mr. de Coene had stated that the experiments made at Rouen with a little model, similar to the one employed by Mr. Vernon-Harcourt, had convinced him that the formation of the proposed neck at the mouth of the Seine would give depths of 23 feet at low-tide from Tancarville to the outlet. He (Mr. Partiot) joined with those who urged the continuation of these experiments and their publication. Mr. Partiot.

Though Mr. Mengin-Lecreulx was struck with the expenditure which this project would involve, he had arrived at his estimate of £4,000,000, to a great extent, from the cost of the Boulogne breakwater and of the Seine training-walls; and of this sum, £2,560,000 would suffice for the works above Havre, the remainder being required for the detached breakwater facing Havre, and for completing the northern channel. Great economy, moreover, might be effected by adopting the system of construction employed by the Dutch, who were about to close the entrance to the Zuider Zee.

Both Mr. Mengin-Lecreulx and Mr. Vauthier had strongly insisted that the construction of the neck would lower the level of high-water in the estuary and above; but the neck at the Pointe

Mr. Partiot. de Grave did not prevent high-water attaining the same level in the Gironde, and up to Bordeaux in the Garonne, as at Royan, and in the Foyle, the tide rose higher at Moville above the neck than at Warrenpoint below. Moreover, in these two estuaries, the tide fell again directly after high-water; whereas, at Havre, high-water lasted for over two hours, facilitating the filling of the estuary. Observation was therefore opposed to this objection. Though the section, moreover, of the mouth of the Seine from Havre to Villerville, with a length of 30,840 feet and an average depth of 21⅔ feet, amounted to 69,255 square yards, as compared with 44,764 square yards at the neck, yet the greater depth of 58⅓ feet at mean sea-level in the neck would render the section through the neck capable of discharging slightly more, with the same average slope, than the other. The tidal wave also would be propagated more easily through the new entrance than at present, since the rate of propagation, according to Lagrange's formula, was proportional to the square root of the depth, and in the neck would be 1·69 times its present rate.

In calculating the loss of height of high-water in the estuary, Mr. Vauthier had supposed that the loss in the neck at any given time was proportional to the square of the height of the water above low-water; but De Prony's formula of discharge showed that the height of the water must be reckoned from the bottom, and not from low-water. Observation proved that the loss of height of high-water was generally nothing in estuaries, and that the tides passed easily through necks, as explained by the foregoing reasons, and would be the same for the Seine, and, therefore, he need not discuss Mr. Vauthier's calculations.

It had been asked by Mr. Mengin-Lecreulx what would happen during the execution of the works. Mr. Partiot believed that it would depend on the way in which they were carried out. He considered that they should be begun by the Villerville breakwater, as recommended by Mr. Caland, as the inner works would thus be executed much more easily and cheaply. In commencing the breakwater at Villerville by closing the south channel, and by beginning the foundations of the breakwater in the middle channel, the outlet channel would go to the north of the Amfard bank as it had done several times; and when, in March 1893, it had taken the course which he desired to give it, the Chamber of Commerce of Rouen ascertained that it was in a good condition. Inside the estuary, directly the opening at Tancarville had been made, the northern training-wall should be prolonged, to prevent the channel from going away from Honfleur. The low training-wall on the left bank

Mr. Partiot.

beyond Honfleur would be constructed towards the close of the works, when silting-up had begun in the triangle between the breakwater and Honfleur.

Though there was no bar in the channel penetrating the estuary between the Amfard and Ratier banks, it might be said that the sands of the estuary discharged by the neck would create a bar at the mouth of the Seine. This bar, however, would be formed like that of the Rhone; but the neck being connected with the central channel, it was certain that the bar would be formed at the extremity of this channel, in the depths of 60 feet below zero which were found near Havre. The bar of the Mersey was 9½ miles beyond the neck, and the bar of the Gironde 15 miles from the Pointe de Grave. Small-scale models might give useful indications on this point; and Mr. de Coene had mentioned that the Rouen model had shown a depth of 26 feet over the bar. In any case, he believed that the Antifer current would drive the sands on to the Seine bank, and that the bar would eventually disappear.

According to Mr. Mengin-Lecreulx, the opinion of French engineers was opposed to the scheme; but Mr. Partiot had received very different assurances; and the erroneous views of the Commission of 1885, the resulting obligations, and the situation of the Government in France, must be taken into account. Mr. Mengin-Lecreulx had declared that the Seine possessed a neck, and that it had only a limited depth; but no neck was now visible in the Seine, which flowed into its estuary through a gradually widening channel. He had also added that the navigation of the Gironde was beginning to meet with difficulties; these did not, however, arise from the neck, whose influence ceased 12½ miles above, but from the changes of the channels in the upper part of the estuary, and of the two large rivers which flowed into it. The existence of a neck was evidently not a remedy for every evil, but if the present condition of Havre was compared with the results hoped for from the proposed scheme, it was clear that this port would be far from suffering any loss. Though Mr. Mengin-Lecreulx considered that the approaches to Havre would be encumbered by the deposit of sands coming from the Seine bank and the estuary, nevertheless, when this port was given two approaches and depths of 33 feet at its entrance, no dangerous bar would be formed in the north channel; the bar in the south-west channel could be lowered by dredging, and the Antifer current would eventually disperse it. The Government desired to achieve success with two separate projects for Rouen and Havre, in spite

Mr. Partiot. of the natural connection between the fixing of the channel in the middle of the estuary and the silting up of the ports of Honfleur and Havre; and he could not approve of the adoption of such a course.

It was urged by Baron Quinette de Rochemont that rivers might be cited as being with or without a neck, according to the theory it was desired to establish, and denied that the Foyle was comparable to the improved Seine. The chart, however, of the Foyle reproduced almost precisely, when viewed on the reverse side of a tracing, the main features of the Seine scheme as carried out by nature, as well as the details of the surroundings, such as the rivers Touques and Rille, Fig. 15, Plate 4, and *Fig. 16*. The waters of the Foyle were clear, whilst the Seine also brought very little silt down during floods. The north winds which caused the travel of the sands along the coast, directed them near the Foyle, and also the mouth of the Bann towards the west, just as the north-west winds in the channel pushed them eastwards near the Seine, and turned the outlet channel of the river Touques in the same direction. The flood-tide coming from the north-east at the entrance to the Foyle could not bring much sand into the estuary on account of the neck which protected it; and the reverse current which, after flowing into the Seine estuary near Villerville, returned charged with alluvium in front of Havre, would not be able to effect this circuit if the southern and central passes were closed; and the sands from the Calvados coast would be arrested by the triangular bank which would be formed on the left bank of the channel beyond the neck, *Fig. 16*, just as the sands which came from the river Bann accumulated on the bank of Tuns, Fig. 15, Plate 4. The current from Cape Inishowen followed the coast, like the current from Cape Antifer; and the littoral current of the Bann was opposed in direction to the other, like the current along the Calvados coast.

The fact was recalled by Mr. Vauthier that the range of tides at the mouth of the Foyle was much smaller than at the Seine outlet; but the only conclusion to be drawn was, that if a rise of $7\frac{2}{5}$ feet at springs gave good results on the Foyle, a rise of $23\frac{3}{5}$ feet would give still better ones. Baron Quinette de Rochemont said that the Villerville breakwater would change the regime of the currents of the estuary; but if this regime was bad, there should be no more hesitation about modifying it than in the case of a sick man to cure him. He (Mr. Partiot) had explained what the new regime at the entrance to Havre would be; and he could not see how the second high-water, which was a purely marine phenomenon, and which reached Havre in following the coast of Antifer, could cease

to be produced. The port of Trouville would retain approximately its present condition, for the travelling sands from the Calvados coast would continue their course along the shore near the breakwater until arrested by the triangular bank below the neck, just as the river Bann had not been silted up by the sand travelling along the coast towards Macgilligan Point, which accumulated at Tuns bank. The deposits which had taken place within the last few years in the Seine estuary were partly due to the displacement of the banks in it; but they must also be attributed to the great width ($5\frac{3}{8}$ miles) of the mouth, all along which the flood-tide could bring in the sands, which the ebb, dispersed over this wide outlet, was powerless to drive out to sea. Trumpet-shaped estuaries were silted up when the channel became fixed, and this had been the effect of the training-works down to the mouth of the Rille; but the same was not the case in estuaries protected by a contracted outlet; and it was to be regretted that the works in the Seine estuary were not commenced by the construction of the Villerville breakwater. Experiments with small-scale models might give different results according to the manner in which they were worked; and he would urge the continuation of the Rouen experiments, which might furnish very different conclusions to those drawn from them by Baron Quinette de Rochemont. Mr. Vauthier considered that the differences in each outlet involved a separate problem for each, and did not take into account that nature acted in accordance with general laws, which were essential to know, and which might often be utilized. He said that the system of necks might be advantageously used within certain limits for tideless rivers; and he (Mr. Partiot) agreed with him that, when such a river dispersed its waters over a great width at its outlet, it might be useful to concentrate them in a single point, which was effected by closing the secondary branches of a delta. Mr. Vauthier, however, found it difficult to understand the advantage of introducing a large quantity of tidal water into an estuary or a river through a neck, in order thereby to obtain an improvement; but the greater the volume of water which entered, the greater and deeper should the channels become. Observation showed that when the volume of tidal water introduced was diminished the depth soon decreased and estuaries silted up, and that it was most essential to avoid as much as possible the reduction of the tidal water. Mr. Vauthier, in criticising the proposed scheme for the Seine, had stated that the training-walls were to be prolonged without increasing the widths of the river; but it had been shown by the case of the Gironde that the essential Mr. Partiot.

Mr. Partiot. point was for the sections, and especially the discharges, to increase seawards, and that these conditions were fulfilled in the arrangements of the scheme. He did not question the importance of the range of tide, about which Mr. Vauthier was so much concerned; but the laws of nature which he had pointed out applied to little ranges as well as great; and the limit of 13 feet, chosen by Mr. Vauthier, was neither fixed nor justified. A reduction in the width of the neck by the travel of the sands, as in the case of the Foyle, might produce depths greater than proportionate to the range of tide; for, whereas the Gironde at the Pointe de Grave, with a rise of tide of 17⅞ feet and a width of 5,300 yards, had a depth of about 100 feet, the Foyle with a rise of tide of only 7⅞ feet, but with a width in the neck of only 1,475 feet, attained a depth of nearly 70 feet. Mr. Vauthier had objected to the examples cited, commencing with the Foyle, and had dwelt on the inconveniences they exhibited in spite of the existence of a neck. He (Mr. Partiot) did not pretend that this condition exempted them from all defects; and he had confined himself to deducing from these examples, that necks produced great depths in the necks themselves, and channels above and below. He had taken account in his formulas of the discharges of the rivers, as well as the range of the tides; and he did not think that a classification based upon these ranges could prove that the natural laws he had indicated were inexact, as Mr. Vauthier supposed.

Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 2711.*)

"The Removal of the 'Iron Gates' of the River Danube."

By Oscar Guttmann, Assoc. M. Inst. C.E.

The term "Iron Gates" is often applied, by those who are only superficially acquainted with the Danube, to denote all the obstructions to navigation on the lower Hungarian portion of the river. The part of the Danube that has to be regulated and improved, so as to make navigation practicable and safe under all conditions of water-level, is that between Bazias and Sibb, a length of about 82 miles, *Fig. 1.* Strictly speaking, it is only the lowest group of obstructions that are called the Iron Gates. Although these are most dangerous to navigation, they present by no means the greatest engineering difficulty to be overcome. How serious an impediment this particular section of the river is to the use of the Danube as a navigable waterway may be judged from the fact, that for about only one-half of the time it is not blocked by ice can vessels pass along this part, on account of the lowness of the water-level, due to the configuration of the river-bed; and for the greater part of this time special vessels of not more than 6 feet draught have to be used. Whenever the river falls below 11 feet 6 inches above datum, even these special vessels have to be lightened by discharging part of their cargo, and at 3 feet above datum navigation becomes impossible, even with rafts. At this state of the river, the cargoes have to be transferred by carts to the railway, and are taken as far as Turn-Severin, where the river is again navigable, and there transferred to boats. This re-handling, of course, largely increases the cost of transport—to nearly £2 per ton. With many classes of goods, it cannot be effected, and such consequently have to wait for a more favourable condition of the water-level before they can be forwarded.

Exclusive of a number of isolated rocks, the obstructions to navigation between Bazias and Sibb may be divided into four sections: the Stenka rapids, the Kozla-Dojke rapids, the Greben section, and the Iron Gates. At the Stenka rapids, *Fig. 2*, there

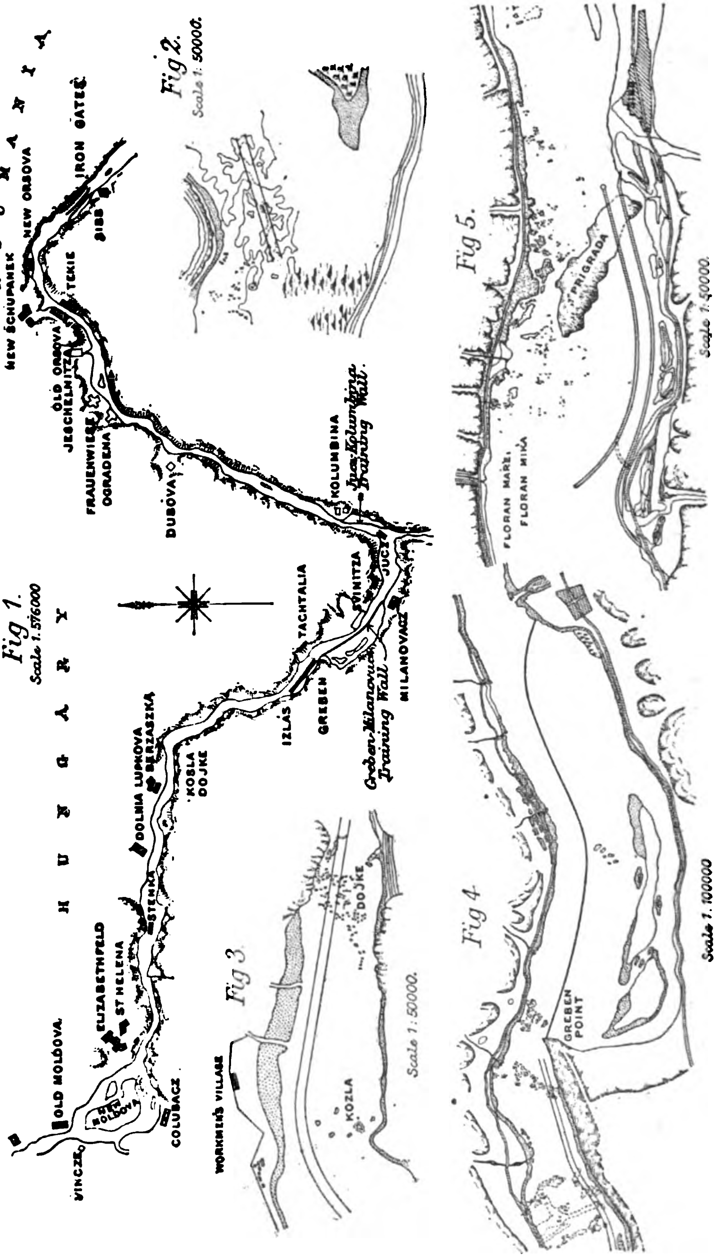


Fig 1.
Scale 1:576000
HUNGARY
ROUMANIA
OLD MOLDOVA
VINCZE
NEW MOLDOVA
COLUBACZ
ELIZABETHFELD
ST HELENA
STENKA
DOLNIA LUPKOVA
BERZASZKA
KOSLA DOJKE
IZLAS
GREBEN
Greben-Milanovacz Training Wall
MILANOVACZ
TACHTALIA
POINITTA
JUC
KOLUMBINA
Juc-Kolumbina Training Wall
DUBOVA
OGRADENA
FRAUENWIESE
JESCHELNITZA
OLD ORSOVA
NEW SCHUPANEK
TEKIE
NEW ORSOVA
SIBB
IRON GATES
Fig 2.
Scale 1: 50000.
Fig 3
WORKMEN'S VILLAGE
KOZLA
DOJKE
Scale 1: 50000.
Fig 4
GREBEN POINT
Scale 1. 100000
Fig 5.
FLORAN MARE
FLORAN MIKA
PRIGRADA
Scale 1:50000.

is a bank of rocks, some of which are dry at low water, extending almost across the river, which here is about 985 yards wide. The fall of the river-bed is small. The length of these rapids is about 1,100 yards. The Kozla-Dojke rapids, *Fig. 3*, extend about 1½ mile along the river, and are situated some 9½ miles below the Stenka rapids. The river here is from 169 to 330 yards wide, and the fall is about 1 in 1,000. These rapids are caused by two banks of rock, which cause very sudden alteration in the direction of the current. At a distance of 5⅔ miles further down the river is the Greben section, *Fig. 4*, where there are a number of formidable obstacles. The regulation of the river here is certainly the most difficult part of the whole work of improvement. First, there is the Izlás bank, and close to it the Tachtalia mare and mica (large and small Tachtalia) banks. A spur of the Greben mountain running out into the river just below suddenly reduces its width from 2,300 feet to 1,400 feet at high water; whilst at low water, on account of adjacent rocks, the width is only half this. Immediately below these narrows the river widens out to about 1½ mile, forming the Milanovacz bay. This group of obstructions ends about 7 miles further down stream with the Jucz rapids, where there is a multitude of small reefs. At the lowest river level there is only a few inches depth of water here, and the river-bed has a fall of 1 in 433. The Iron Gates, *Fig. 5*, properly so called, are situated about 34 miles below the Greben point. The chief obstacle here is the Prigrada bank, which, with the innumerable small banks on the left, nearly blocks the river, and behind it there is a sudden fall of 3 in 1,000 in the river-bed.

The advantage of having a continuous waterway up the Danube has long been recognised. The Romans, under Trajan, were the first to attempt its construction. Traces are still visible of the canal they cut, and afford evidence of the great labour expended upon the undertaking. No further attempt seems to have been made until the present century, during which local removal of rocks by blasting has from time to time been effected. The first person who took up the matter seriously was the Hungarian patriot, Count Stephen Széchenyi, who, with his engineer, Paul Vásárhelyi, worked indefatigably to prepare all the necessary plans, and endeavoured to inaugurate this great undertaking. Political and financial difficulties prevented the execution of their scheme, although every detail of it was carefully worked out. It was left for Gabriel Baross, Under Secretary, and afterwards Chief Secretary of State for Commerce, to give, in 1883, a practical start to the affair. The preparation of the plans and deciding upon the

method of working was entrusted to Mr. Ernst Wallandt; and whilst the broad outlines upon which the regulation could best be carried out had been shown previously by experts of various nationalities, Messrs. Vásárhelyi and Wallandt—both Hungarians—are alone responsible for the engineering details of the work. Before tenders were invited, the whole of the river-bed was surveyed, bench-marks were placed in position, and the quantity of rock to be removed and that required for building the training-walls was calculated. In the meantime a public competition was instituted, with a view to determine the best method of removing the subaqueous rocks, especially those at Jucz, and the most suitable explosive to use. The result of the competition not being satisfactory, the Government decided to leave the details of the execution to the contractors. Only two tenders were received, and the work was finally entrusted to a company consisting of Mr. Hajdu, a Hungarian engineer, Mr. Luther, of Brunswick, and the Berlin Discount Company.

The work to be done may be thus summarized:—

At Stenka, Kozla-Dojke, Izlás and Tachtalia, channels 66 yards wide have to be cut to a depth of about 6 feet 6 inches below low water. The point of the Greben mountain has to be entirely removed for a distance of 167 yards back from its original face, and to a depth of about 6 feet 6 inches below the low-water level. This is to prevent the swelling of the river above the Greben point, on account of the sudden narrowing of the river-bed at this spot. Below the Greben Point, where the river widens out rapidly, a training-wall nearly 4 miles long has to be built along the Servian shore, in order to obtain sufficient depth of water, by confining the river in a narrow channel. This training-wall is between 7 and 9 feet high, 10 feet wide at the top, battered at 1 to 1½. To connect it with the shore, and to equalize the water-level behind the training-walls, there are two dams, 6 feet 6 inches wide at the top. At Jucz, a channel of similar dimensions to those just mentioned has to be cut, and a training-wall built between the Porecska brook and the Golubinji island. At the Iron Gates, a channel 89 yards wide and about 3,000 yards long has to be cut to a depth of 6 feet 6 inches below low-water level along the Servian side of the river, passing through the Prigrada bank, and terminating at the village of Sibb. The depth mentioned not giving sufficient water for purposes of navigation during a great part of the year, training-walls on each side of the channel are being built to confine the water so as to raise its level. The right-hand wall is to have a width at the top of 19 feet

6 inches, and will serve as a tow-path; the left wall will be 13 feet wide at the top, the batter of both being 1 to 1½. After the greater part of this channel had been blasted to a depth of 6 feet 6 inches, it was decided to increase the depth to 13 feet below low water, in order to allow small war-vessels to get up as far as Orsova, and at the end of 1891 powers were obtained to carry out this alteration. It will, of course, give at the same time much greater facility for trade, and will probably make Orsova a large trading centre. All the training-walls are being built of stone, and have flat revetments to protect them against ice. For those at Greben, the stone from the Point is utilized.

The quantities of work to be executed are, according to official details, as follows:—

Place.	Removal of Rock in the River.	Removal of Rock on Shore or in Shallow Water.	Stone-depositing on Dams.	Various Dam work.	Stone Revetment.	Depositing Stone.
	Cubic Metres.	Cubic Metres.	Cubic Metres.	Cubic Metres.	Cubic Metres.	Cubic Metres.
Stenka . . .	7,400					
Kozla-Dojke .	65,800					
Izlás Tachtalia .	46,800	..	505,600	..	..	106,300
Jucz	3,200	..	70,000	..	..	29,000
Iron Gates . .	..	227,000	294,000	270,000	68,400	
Between rapids	10,000					
Totals . .	133,200	227,000	869,600	270,000	68,400	135,300

The rock at the Stenka rapids is granite and crystalline slate, at Izlás and Tachtalia mare porphyritic tufa. The Tachtalia mica and the Greben mountain consist of quartzite and limestone. At the Iron Gates, the rock is a hard arenaceous limestone. The total cost of the work is estimated at £725,000 sterling, and the contractors have undertaken to complete the work before the end of 1895. Work was commenced on the 18th of September, 1890.

The most striking feature of the operations, as they are now being carried out, is their extreme simplicity. Colonel Lauer's method of subaqueous blasting, which was originally thought to be the only one available, and on which the first estimates were based, has been found unsuitable for these works; although it gave most satisfactory results in the preparation of the bridge foundations at Peterwardein on the Danube. This system is carried out by mooring in the usual manner a barge, having over

the front a wrought-iron framework with a number of apertures, through which a rod made of gas-tubing can be slipped down to the river-bed from a fixed point overhead. A number of equidistant points can thus be touched. On the end of the rod a charge of 2·2 lbs. of dynamite, in a tin case, fixed to a short wooden rod, is attached by a suitable holder. The charges are fired electrically, and usually only the wooden lengthening-piece is broken. The rocky bed of the river is removed in steps, with the free side down stream, so that all the small débris is carried away by the current. The difficulty experienced in working by this system at the Iron Gates was that when a depth of rock of 6 feet had to be removed, it had to be taken off in three or four layers; on attempting to start the second layer, the shots had very little effect when the rock was soft, and it seemed as if the rock had been compressed by the first set of explosions. In addition, there was also the danger of permanently leaving needle-like points projecting, which would have been most dangerous to passing vessels. Finally, there was the minor difficulty that the wooden lengthening-pieces became so tightly jammed into the iron rod that nothing short of burning them out sufficed to remove them. Whilst for small obstacles Lauer's method was effective and cheap, other methods had to be resorted to for attacking the heavier work.

The first important piece of work is that on the Greben section. The removal of the Greben Point is now finished. As the spur of the mountain had an almost vertical face towards the river, work was commenced on it at two different levels simultaneously, and a tunnel was driven to carry away the spoil. The first material removed was pumped into the river, and sufficient ground made to build locomotive-sheds and workshops, and to form a connection with the little village of workmen's houses. As soon as the rock was cut back sufficiently far from the shore, chamber-mining was resorted to. The chambers were very simple in shape. A heading 3 feet wide by 4 feet high was driven about 80 feet, quite straight; and then a chamber, 6 feet 6 inches cube was blasted out at right angles to it. This was charged in the usual way, and the heading was closed first with brickwork set in cement and then with dry stone-work. The ignition was accomplished electrically. Such a mine would have a charge of 5 tons of second grade new dynamite containing about 45 per cent. of blasting gelatine. At first, carboazotine,[1] a low explosive of the

[1] Carboazotine consists of 74 per cent. of potassium nitrate, 12 per cent. of sulphur, 8 per cent. of soot and 6 per cent. of bran, and is prepared by a wet process.

nature of blasting-powder, was used. One of these chamber-mines fired last year had a breast of 20 yards and a height of 33 yards. According to calculations 3·885 tons of carboazotine was the charge required, so a charge of about 4 tons was used. The result was that about 700,000 cubic feet of rock were thrown down. The largest blast hitherto made was fired in May 1894, when 2,100,000 cubic feet of rock were thrown down by a charge of 12 tons of second grade dynamite. In both cases, about 80 cubic feet of rock were removed per lb. of explosive.

The formula used for charging the chamber-mines was

$$L = 3\ (v^3 + 5h)\ q,$$

where L is the weight of the charge in kilograms, v the line of least resistance in metres, h the height in metres of the rock above, and q a coefficient depending on the explosive used; for carboazotine, this was found to be between 0·18 and 0·23, but was usually taken as 0·22.

The height of the rock seems to be of little importance, as the omission of the term $5h$ from the calculation only makes a difference of 100 kilograms in a charge of 4,000 kilograms. Thus the formula practically resolves itself into the cube of the line of least resistance multiplied by a coefficient. This is almost identical with the formula obtained by considering the explosive to act in spherical waves in an unlimited homogeneous solid, namely, $L = 4{\cdot}1888\ r^3 c$. This is the formula used in the harbour works at Fiume, where the ratio of height to line of least resistance was kept constant at 3 : 2. Both these formulas give the quantity of charge too high, since they can only be true in a perfectly confined space,—a condition which never occurs in practice, for there is always at least one free surface,—and consequently the formula based on the formation of a conical crater must be more accurate. This formula is—

$$L = k\ (w + r)^3,$$

where L is the weight of the charge in kilograms, w is the longest line of resistance at right angles to and towards the free face in metres, and r is the radius of the crater in metres, which should not be more than $\frac{3}{2}\ w$. As an additional quantity of charge is desirable to ensure success, the spherical-wave formula may be used, though at some extra expense. As previously stated, the stone thrown down from the Greben Point is utilised in building the training-wall along the Milanovacz shore. The measurement of the quantity of material put into the training-wall is attained

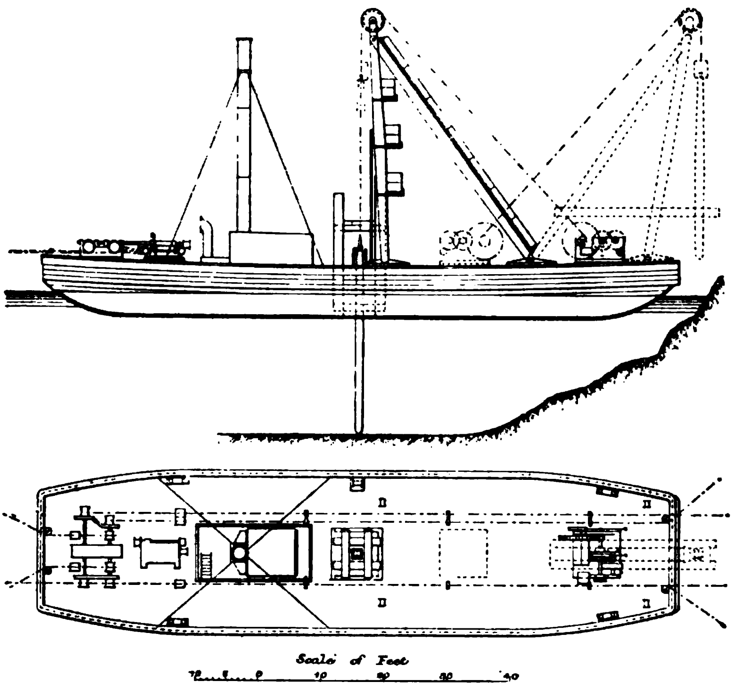
by weighing the loaded trucks, the weight per cubic metre of the piled stone having been previously determined, and being from time to time checked; and payments to the contractor are made according to the number of cubic metres of training-wall built, calculated from the weights of broken rock sent on to it. The training-walls are being built by tipping the rock from trucks running on a line of tramway laid along the top of the wall, and by barges at the more distant part, from which the rock is thrown out by hand. Some difficulty was experienced at Greben in mooring the barges; rings fixed in the ordinary way would not hold, on account of the very strong current and occasionally high water-level. By using a ring bolt with a split end, and driving it on to a steel wedge placed at the bottom of the bolt-hole, a perfectly secure mooring-ring was obtained.

The work that presents the greatest difficulty is the cutting of the channel through the Jucz rapids. This channel, which has a width of 197 feet, has to be accurately cut through a mass of submerged reefs, to a depth of 6 feet 6 inches below low water. A mixed system of rock removal has been decided upon for cutting this channel. In parts where the average depth is sufficient, with isolated rocks scattered about, Lobnitz cutters are used for levelling the bed of the channel. Where large reefs of considerable thickness have to be cut through, machine drilling and blasting is adopted. The rock-cutting machines employed are similar in principle to those described by Mr. Fred Lobnitz, Assoc. M. Inst. C.E., in his Paper on "The Removal of Rock under Water without Explosives."[1] This method consists of shattering the rock by the blow of a heavy bar allowed to fall freely from a height on to the face of the rock. The machines in use at the Iron Gates are somewhat different from those described in the Paper alluded to. They have only one cutter in place of ten. With the rapid current and other local conditions on the Danube, a machine with one cutter of great weight is more suitable than a larger machine with a battery of cutters of various weights. The general arrangement of one of the machines used is shown in *Figs. 6*. The barge is 100 feet in length, 25 feet broad, and 7 feet deep, with a draught of about 3 feet. The boiler is placed near the stern; abaft the boiler are the manœuvring winches, for moving the vessel along the main and the four side-chains. Near the centre of the vessel is the tripod, or sheer-legs, for manipulating the cutter, the hoisting-winch of which is placed in the fore part of the barge. The cutter is, as a rule, dropped through a well in

[1] Minutes of Proceedings Inst. C.E., vol. xcvii., p. 369.

the centre of the barge, but arrangements are made for swinging over the tripod so as to allow the cutter to work over the fore end of the vessel. The action of the machine is that of a pile driver, the pointed cutter-bar replacing the "monkey" of the ordinary pile-driver. The cutters consist of wrought-iron or mild steel bars 30 feet long, square in section. They are 7 inches square at the top, increasing to a maximum of 13 inches square, 10 feet from the point, and diminishing again to 11 inches square at the lower end.

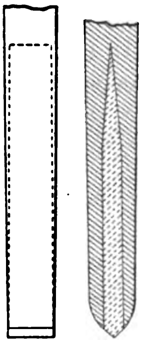
Figs. 6.



For a length of 4 feet at the lower end, a hard steel core 11 inches by 4 inches is welded in along the centre line of the bar. The point of the bar is chisel-shaped, the sides being shaped off to a 9-inch radius. The cutter is hardened by heating the point to a cherry red and dipping it into the water. Details of the cutter are given in *Figs. 7.* This steel blade, being protected on two sides by wrought-iron, can be used up to the last few inches, and always keeps sharp; its weight is about 8½ tons. Sometimes a cutter 24 feet long is used. The cutters have a scale painted on

them so that the depth of the river can be measured. When the rock at one particular spot has been shattered the barge is moved sideways, and when a width of 20 inches has been broken away the vessel is advanced that distance. The rock is removed 1 foot more than the specified depth, so that the possibility of leaving spurs of rocks that would be dangerous to boats is avoided. The varying hardness of the rock prevents an accurate account of the rate of work being given. The drop given to the cutters is 5 metres, and from fifty to one hundred blows per hour the average speed. The rate of working depends upon the necessary amount of shifting and manœuvring of the barge, which is larger when the rock has to be removed to a small depth than when it is thicker. The average amount removed per blow is 2 cubic feet of the hard rock at Jucz. One great advantage of this system is that the broken stone is always small enough to be easily removed by ordinary dredgers. Up to the middle of August 1893, 22,315 cubic metres of rock had been broken down by Lobnitz cutters, by far the largest portion of this having been done in 1892, only 7 per cent. of the total work having been accomplished at the end of that year. There are two of these rock-cutting machines at work, and a third one, which has a platform supported on two barges for carrying the machinery instead of one large barge. They are working in a most satisfactory manner and are giving very good results.

Figs. 7.



The blasting operations and the drilling of the bore-holes are also conducted from specially-constructed barges. There are two systems at work, namely, that of the Ingersoll-Sergeant Drill Company at Jucz, and the Fontane system at Izlás and Tachtalia. The Ingersoll "scow," as the makers term it, is provided with spears, one at each corner, up which the scow can be raised by hydraulic jacks fed by a Worthington pump. This enables the scow to be lifted out of the water so as to rest on the four spears, thus giving a working platform independent of the movement of the water. The arrangements for manœuvring the scow are similar to those on the rock-cutters described. Along one side of the barge rails are set, carrying four 4½-inch Ingersoll drills worked by steam supplied by a boiler on the scow. As the current is strong in this part of the river and carries a good deal of detritus, a protecting tube, held by a special iron framework and pressed against the river-bed, surrounds the drilling-bar. When the

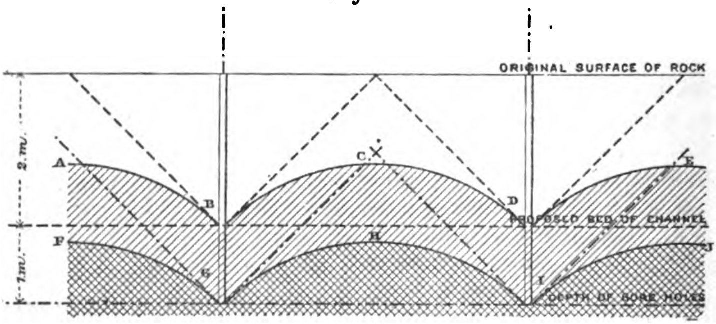
drilling of a hole is finished, it is washed out by a jet of water and the charge of dynamite is lowered into the bore-hole through the protecting tube, which is split along one side to allow the wires of the electric fuze to pass. The dynamite charges are enclosed in tin cases, having an iron weight attached to their lower ends to keep them in position. When all the bore-holes for one blast have been charged, the scow is lowered on to the water, and floated away to a distance of about 50 feet, the charges being fired simultaneously by electricity. The Ingersoll scow is said not to be perfectly steady, and the blows of the drill cause a rather excessive vibration. The protecting tube does not invariably fulfil its object, on account of its lower end failing to become truly bedded all round on the rock, and the bore-hole sometimes becomes choked with mud. Two of these scows have already been blown up, the charges having become jammed as they were being lowered through the protecting tube, and the workmen having thereupon attempted to force the charges down with a boring bar. On the whole, however, the two Ingersoll-Sergeant blasting and drilling scows at work at Jucz have given satisfaction.

In the Fontane system, two barges are coupled by a platform on which the drills are mounted. This system gives a much greater range of work than that previously described without moving the platform, which is of advantage in reducing the time lost in manœuvring the drilling-platform. The twin barges should also give much greater steadiness to the platform, but, unfortunately, the Fontane barge has been built too slightly, and there is consequently a great deal of vibration; so that the work which is being done by this system has not yet been satisfactory as regards quantity. A stronger barge is, however, to be built, as the system is thought highly of on these works.

Special care has to be taken to leave no reefs in the proposed channel. If the bore-holes were only drilled to the intended depth of the canal, such reefs would inevitably be left, as will be seen from the diagram, *Fig. 8*, which shows the probable effect of two bore-holes fired simultaneously by electricity. If the bore-holes were only put down to the level of the bed of the proposed channel, the latter after blasting would have approximately the form shown by the line A, B, C, D, E, *i.e.*, a projecting piece would be left between each pair of bore-holes. To avoid this, the holes are always drilled 3 feet deeper than the proposed bed of the canal, so that the bed left after blasting may be approximately as shown by the line F, G, H, I, J. The highest water-level is 13 feet, and the highest reef is 6 feet 6 inches above

datum. This, with the additional 3 feet required for safety, gives a depth of 22 feet 6 inches to be drilled below high-water mark. The explosive used is new dynamite No. 1, which is similar in composition to gelignite in England. The rock broken away by the cutters and by blasting is removed by dredgers. That broken away by blasting was expected to give some trouble, as much of it consists of large lumps, and dredging it is by no means an easy or cheap undertaking. Some of the dredgers are of the Priestman type, others are ladder-dredgers with buckets. Messrs. Lobnitz and Co., of Renfrew, built one specially for dredging the larger rocks. This was a sea-going dredger, and made the voyage, remarkable for a vessel of this type, from Renfrew to Jucz *viâ* the Black Sea, in forty-five days, under her own steam. The dimensions of this vessel are:—length between perpendiculars, 130 feet; breadth, moulded, 33 feet;

Fig. 8.



and depth, moulded, 11 feet. Her draught when at work is 6 feet, which enables her to dredge in the shallowest part of the works. She is specially designed for rock excavation, and is fitted with strong steel buckets and elastic pitch chain drive, one element of which weighs $1\frac{1}{2}$ ton. The dredging-machinery and the propellers are actuated by a compound surface-condensing engine with direct-acting inverted cylinders. The high-pressure cylinder is 16 inches in diameter, the low-pressure cylinder 30 inches in diameter, and the stroke is 2 feet. This engine, which indicates about 250 HP., can be connected at will with either the dredging-machinery or the twin-propellers with which the vessel is fitted. Besides this engine, there are auxiliary ones for driving winches, &c. All the machinery in the dredger is controlled by levers placed forward, which are manipulated by the dredging-master, who has thus absolute control over the dredger.

The work at the "Iron Gates" proper is of an easy character compared with that in the Greben section, although it is perhaps of more general interest on account of its vast dimensions. As shown in *Fig. 5*, the channel to be made there will be bell-mouthed at both ends; so that under the most unfavourable conditions sufficient water will flow through to give the desired depth. The work was commenced by building a cross-dam, diverting the river, and leaving the route of the proposed channel dry. The two training-walls were then simultaneously built, and a small channel was cut to carry away water leaking in. The cutting of the permanent channel along this dried river-bed presents no difficulties. The whole of the blasting operations are performed by hand; the broken rock is carried away in trucks drawn by locomotives to a shunting station and then on to the two training-walls. The quantity of rock obtained in cutting the channel being insufficient, a quarry had to be opened about a mile up the river. On account of the bank and the bordering hills being covered to a considerable depth with loose gravel, this quarry had to be opened on the top of a hill some 500 feet high; the stone from it is shot down a steep slide on the hill-side. It is likely that the velocity of the current in this channel will be considerable; in fact, with the depth of 6 feet 6 inches as originally proposed, a velocity of 13 feet per second was expected, and means of towing boats through had to be considered. With the depth of 13 feet, the sudden drop in the bed at the lower end will largely disappear, and it may be possible so to arrange the fall that the velocity of the current in the channel will be reduced to such an extent as to obviate the necessity of towing.

According to official returns, the quantity of work executed up to the end of 1893 was as follows:—

	Cubic Metres.	Percentage of estimated Total.
Blasting under water (of which 67,536 cubic metres have been removed)	122,758	77·77
Blasting at the Iron Gate	307,223	90·60
Stone depositing	345,978	68·93
Various work on dams	133,065	20·05
Stone revetment	9,150	square metres.
Facing dams	56,340	,, ,,

The Paper is accompanied by eight tracings, from which the *Figs.* in the text have been prepared.

(*Paper No. 2855.*)

"Cost of Dredging in the Lower Danube."

By Charles Henry Leopold Kühl, M. Inst. C.E.

In a previous Paper[1] the Author gave some particulars of the works of improvement on the Lower Danube then being carried out by the European Commission, under the direction of Sir Charles A. Hartley, K.C.M.G., M. Inst. C.E. The methods of dredging in use were described in that Paper, and the cost of dredging was given, as based on the work done up to that time. The Table now presented gives the cost of the work which has been done in the years 1890 to 1893 inclusive. It was all effected in making a new cut between 8½ and 18 miles from the Sulina mouth of the river.

The total quantity dredged in these four seasons amounts to 5,926,136 cubic metres, or 7,751,517 cubic yards, and the average cost has been 0·286 franc per cubic metre, or 2¼*d.* per cubic yard. This includes transport by hopper-barges for such part of the stuff as was disposed of in that way, but does not include interest on capital outlay, nor any allowance for depreciation of plant or insurance.

The dredgers work night and day during the working season, in two shifts, from Monday at 6 A.M. to Sunday at 6 A.M. The stuff dredged varies from very hard clay and heavy sea-sand to light silt and fine sand. When using the mud-pump the quantity delivered per week varied from 10,000 to 40,000 cubic metres according to the nature of the stuff. When very hard clay is met with, too stiff for the mud-pump, hopper-barges are brought alongside. The heavy fine sea-sand could only be pumped with great difficulty, as it settled in the floating pipe, causing it to sink. It was found, however, that by increasing the speed of the pumps from 225 to 275 revolutions per minute, almost any material that was met could be dealt with.

The following are the vessels to whose work the Table refers:—

(1) "*Sulina*" *dredger.*—115 feet long, 25 feet beam, 10 feet

[1] Minutes of Proceedings Inst. C.E., vol. lxv. p. 266.

9 inches depth, with single, side-lever, low-pressure engine of 40 nominal HP. Cost, £14,700.

(2) "*Delta*" *dredger.*—124 feet long, 28 feet beam, 10 feet depth, with compound, surface condensing, direct-acting, inverted engine of 180 I.HP. Cost, £16,405.

(3) "*Sir Charles Hartley*" *dredger.*—124 feet long, 28 feet beam, 10 feet depth, 250 I.HP. Cost, £19,440.

(4) *Tug-boats and Hopper-barges.*—Cost, £16,495.

The "Sulina" works, as a rule, with hopper-barges. She was fitted in 1891 with a long shoot delivering 130 feet from the centre line of the vessel.

The "Delta" and "Sir Charles Hartley" work, as a rule, with the mud-pump on Burt's system, and only occasionally with hopper-barges.

EUROPEAN COMMISSION OF THE DANUBE. COST OF DREDGING IN THE 8½ TO 18-MILE CUTTING, 1890–1893.

Name of Vessel.	Quantity Dredged in Cubic Metres.	Working Expenses in Francs per Cubic Metre.		Repairs to Vessel and Machinery in Francs per Cubic Metre.		Total Cost.	
		Coal and Stores.	Crew and Wages.	Stores.	Labour.	Francs per Cubic Metre.	Pence per Cubic Yard.
"Sulina" dredger[1]	1,310,836	0·08123	0·12623	0·33500	0·05617	0·29713	2·181
"Delta" dredger[2]	2,634,946	0·06584	0·07777	0·03337	0·03480	0·21178	1·554
"Sir Charles Hartley" dredger[3]	1,980,354	0·05153	0·07302	0·03732	0·02433	0·18620	1·367
Tug-boats and hopper-barges[4]	Quantity Transported. 1,004,084	0·08823	0·05730	0·00725	0·12413	0·27691	2·033

NOTE.—No allowance is made in the above figures for interest, depreciation or insurance.

[1] Dredging into hopper-barges, and also into long shoot, delivering on shore.
[2] Dredging with mud-pump, and occasionally into hopper-barges.
[3] " " " " "
[4] Average lead 3 nautical miles.

(*Paper No. 2798.*)

"On a Concrete Bridge at Munderkingen."

By K. LEIBBRAND, of Stuttgart.

(Translated and abstracted by P. W. BRITTON, Assoc. M. Inst. C.E.)

THE old bridge over the Danube at Munderkingen—a structure consisting of masonry abutments, oak piles and timber decking—having at the end of 1892 been found to be in a dangerous condition, it was determined that it should be pulled down and replaced; the new bridge being built in an adjacent position, and the old bridge being maintained until the completion of the former.

The highest recorded water-level at the site was 10 feet 6 inches above the mean surface, the span of the old bridge being 173 feet 10 inches. The next bridges crossing the river respectively above and below stream are at Rechtenstein (151 feet span) and at Rottenacker (171 feet span). The clear span given to the Munderkingen bridge is 164 feet. On the town side, the rock, which is of dislocated jurassic formation, appears at the surface; but the stratum is sharply inclined, and falls to 20 feet below the lowest water-level at the opposite side of the river. Excellent sand and gravel being ready to hand, and the Upper Swabian Cement Works not far from the town, concrete was naturally selected as the most suitable material for the bridge. An elaborate series of experiments was made to fix the quality of the cement and its strength in varying combinations, and these are fully detailed by the Author.

DESIGN.

One of the chief and special features of the structure (Plate 5) is the introduction of rows of pivoted bearing-joints or links at the crown and at the springings, which permit of the unavoidable variations in the form of the structure taking place without any disfigurement of the soffit or dislocation of the material. They also assist in framing the arch to the theoretical static line, and

enable the calculated stresses to be adjusted to a nicety in the execution of the work. The bridge is planned and built as a single concrete arch of 164 feet clear span, and 16 feet 5 inches rise. The stresses were calculated on the basis of a live load of 82 lbs. per square foot; and, having regard to the great mass of the bridge, no special allowance was made for any exceptionally concentrated loads passing over the road. The curve of the arch was determined experimentally, and approximates to the line of mean pressure under the full load. The radius from the left-hand springing to the crown is 213·3 feet, from the crown to two-thirds of the distance towards the right-hand springing 229·7 feet, and the remainder 150·9 feet. The thickness of the arch at the crown is 3·28 feet, and the maximum stress 503 lbs. per square inch; at the haunches the thickness is 3·61 feet, the maximum stress on the left-hand side being 506 lbs. and on the right-hand side 513 lbs. per square inch. At the point of incidence of the maximum dead load, where the curve of pressure lies in the outer or inner third according to the loading of the bridge, the thickness of the arch is increased to 4·26 feet, so that the maximum stress should be approximately uniform throughout. Owing, however, to conditions arising in the course of construction, the actual stresses at this point are 540 lbs. per square inch on the left side and 559 lbs. on the right side.

The joints are not continuous, but are twelve in number in the width of 24 feet 7 inches, and they divide the arch practically into two distinct segments, each being separate from the adjacent abutment. The bearing-boxes, which are sunk flush with each concrete face, have a surface of 2 feet 8 inches by 1 foot 8 inches, and consist of two $\frac{9}{16}$ inch wrought-iron plates, riveted to three intermediate rolled joists, the depth over all being 9 inches. Across the horizontal centre of the outer plate is riveted a flat steel rail, $2\frac{3}{4}$ inches wide and 1 inch thick, the two rails on the respective faces of each pair of boxes being fitted exactly to each other on a rolling curve of 6 inches radius. The whole load is therefore transmitted through these bearing-surfaces, the maximum stress on the concrete being 838 lbs. per square inch.

On the base of the right-hand abutment, which is built upon the rock, the maximum pressure is only 213 lbs. per square inch. The shearing strength of the concrete in the abutment is 147 lbs. per square inch, but this is inoperative, as all interstices in the rock are entirely filled with concrete. The load at the base of the spread foundation on the left shore is equal to 29·4 lbs. per square inch on the average (the maximum being 42·6 lbs.), and

the shearing stress due to the horizontal pressure is 50 lbs. per square inch; but allowing for frictional resistance as equivalent to 70 per cent., the net stress is reduced to 17·6 lbs. per square inch. This abutment rests on 145 piles, each carrying a load of 17 tons, giving a total bearing of 2,465 tons. To relieve the dead-weight of the structure, two tiers of voids with vaulted soffits, of 3 feet span with inner spandril walls 2 feet thick, are formed over the arch. The outer spandrils are 3 feet 3½ inches thick. The whole width of the arch is allowed as waterway, and a path 8 feet 3 inches wide is provided for on each bank by an arched passage through the abutments.

The roadway is 17 feet 9 inches in width, and the raised footway on each side, 4 feet 3 inches wide, is carried partly on concrete brackets projecting 1 foot 9½ inches beyond the face of the arch. The curbs and channels are also formed of concrete blocks, the footways being asphalted and the roadway metalled. The bridge being on an incline of 1 in 33⅓, the surface drainage falls naturally towards the left bank. For draining the filled-in material, the voids and spandrils are covered with a layer of cement and one of asphalt, and a half-round channel-bar is built in longitudinally on the centre line of the roadway. To avoid disturbance of the surface, which might be occasioned by rupture of the spandrils under the expansion of the arch due to variation of temperature, free spaces are allowed across all these walls and arches sufficient to provide for all such variations, the upper surfaces of the openings being covered by iron angle-bars sliding one above the other. The parapet railings are formed of wrought-iron and steel, the standards being of iron channel-bars sunk and fixed in cast-iron sockets.

Construction.

The Portland cement was purchased, under the engineer's orders, direct from the Ehingen-Blaubeuren Works, and the work was carried out by contract. The building operations began in April, 1893. On the right bank the excavation for the foundations was attended with but little difficulty. On the left shore the ground was dredged by hand, and the 145 piles were then driven at an inclination of 15° from the perpendicular, with rams weighing 8 cwt. and 11 cwt. respectively. The pumping plant, lifting 660 gallons per minute, was sufficient to reduce the water in the excavation to a depth of about 1 foot 6 inches. The concrete was made with quick-setting cement, and was shot down in hoppers,

the suction-pipes of the pumps being covered with porous material so as to prevent the fresh concrete from being washed away. The concrete for this foundation was mixed by hand, but a mill was used for all the rest. The scaffolding and centering of the bridge rested on twelve rows of piles. The bridge crosses the river obliquely (the skew angle being about 15°), and some difficulty was experienced in the erection of the framing. The sole-plates rested on the piles, and were secured to the decking by oak dowels. It was originally intended to make the arch in two widths; but, on account of the short time at disposal, the whole work was carried out in one width.

The iron joints at the haunches were fixed about the middle of July, before the arch was commenced. The centering was also, before the construction was proceeded with, loaded at the crown with 25 tons of sand, iron and other materials. Moulding-boards (corresponding with winding-strips) were then erected at intervals of from 3 to 5 feet, and in three longitudinal divisions. The centering-boards were covered with strong packing-paper, well soaked with linseed-oil, and wedge-shaped fillets were nailed over this to give the soffit the appearance of courses on an ashlar intrados. The moulding-cases or divisions were then filled up with concrete in 12-inch layers, well rammed. The faces of the arch were lined with planed boards, on which wedge-fillets were nailed to give the appearance of voussoirs. The whole of this woodwork was well oiled. The facing, to the depth of 4 inches, was made of one part of coloured cement to two parts of sand, carefully spread and rammed. The concrete, of moister mixture than elsewhere, was then filled in to the mould and was perfectly incorporated with the facing. Cement joints were also put in where the concrete had become set, so as to ensure perfect bonding throughout.

In consequence of insufficient support at the ends of the centering, the haunches sank nearly ½ inch during the construction of the arch, and the faces of the steel joints were shifted from their bearings. It was therefore necessary to take out some of the concrete on each side of the joints, so as to allow of their being adjusted and refixed in proper position. They were then screwed and wedged up into place, and afterwards kept their bearings.

Early in August the joints both at the crown and at the haunches were embedded in concrete, and the arch was entirely closed within three weeks afterwards. Ten days after the closing of the arch the crown was eased to the extent of 1·18 inch, to counteract swelling on the centering, the latter being kept constantly moist

during the whole process of setting. The centering was struck after the lapse of twenty-eight days, the set at the crown being about 3 inches. The final set, after a period of five months and with a range of temperature of 40° F., was $5\frac{3}{4}$ inches. In the left abutment the horizontal extension of the span was $\frac{1}{4}$ inch, and in the right abutment $\frac{1}{8}$ inch, with a depression of $\frac{1}{16}$ inch. The interstices at the iron joints were filled up with cement-mortar before the erection of the spandrils and as soon as the arch had sufficiently settled. This cementing was done to preserve them from the effects of exposure to the weather or from any interference, but was not essential to the stability of the arch, and in no way affected the distribution of the stresses. The variation in level at the crown of the arch for a range of temperature of 100° F. amounts to 2 inches.

In order to improve the elevation of the bridge the concrete surface was finished in cement in different shades. Thus the voussoirs were faced in a reddish tint to imitate sandstone, as were also the imposts and the keystones and string-courses to the side openings and abutments. The parapet walls and columns at each side were tinted a pale green, and projecting panels were finished by hammer-dressing. The outer spandrils are faced with rubble blocks of jurassic limestone set in cement.

The bridge was opened for traffic on the 16th of November, 1893, the construction having occupied a period of seven months.

Cost.

The cost of the bridge was as follows:—

	£
Foundations	700
Centering and scaffolding	355
Materials and labour	2,020
Supervision and sundries	475
Total	3,550

On the span of 164 feet this is equivalent to £7 8*s.* 6*d.* per square yard. If the measurement is taken between the centres of foundations, the cost is £6 5*s.* 6*d.* per square yard. The total cost of the bridge and approaches was £4,500, of which the Government, by whom the supervision of the work was undertaken, contributed £1,650, the remainder being borne by the Municipality of Munderkingen.

The total quantity of Portland cement used was 552 tons. The cost of the concrete, inclusive of all items of carriage, labour, machinery and staging, was 3*s.* 4*d.* per cubic yard. The average daily wages of an ordinary labourer was 2*s.* 7*d.* The cost of pile-driving averaged 19*s.* per pile. Each of the bearing-joints with boxes complete cost £5 15*s.*

The Paper is accompanied by a photograph and four sheets of illustrations, from which Plate 5 has been compiled.

(*Paper No. 2803.*)

"Indian River-Steamers."

By Hugh Callaway, Assoc. M. Inst. C.E.

Notwithstanding the extension of railways in India, the river traffic continues to increase both as regards passengers and cargo, and that on the tributaries of the Brahmapootra, Ganges and Megna will always remain untouched by railways. Recently, owing to the development of the Assam and Cachar districts through tea-culture and other industries, the river-steamboat companies have been obliged to meet the demands of the traffic with new specially-designed vessels. Of these the Author proposes to describe two types designed by him for service on the Cachar and Assam rivers. The first is a feeder boat, which taps the small tributary rivers and brings down to the main line of the despatch service light cargo and passengers; the second is a main-line despatch vessel, which on the Assam service performs an upward and downward trip of 600 miles each way, carrying mails and passengers as well as emigrant coolies for tea-gardens and goods for quick despatch.

For the feeder boat the following points had to be kept in view—to attain which much that might otherwise have been considered as conforming to present ideas has been sacrificed: Extremely light draught was necessary, with speed up to 10 miles per hour, and a fair carrying-capacity at 2 feet immersion. The length of hull was limited to 100 feet, owing to the extremely quick bends in the small rivers. Large deck space was also essential—as many as 250 native passengers with their baggage having to be provided for. The hull, while as light as possible, had to be capable of withstanding the rough usage to which the craft is exposed when plying in narrow and winding rivers, owing to frequent collision with the banks and grounding in the shallows. As regards machinery, the foremost consideration was that it had to be driven by a native hundreds of miles from any repairing-shop, which rendered simplicity and strength to rank in importance before economical efficiency.

To meet these requirements, a stern-wheel steamer 100 feet × 20 feet × 4 feet was constructed, Figs. 1 and 2, Plate 6. The hull of the vessel is of the best Siemens-Martin mild steel $\frac{4}{32}$ inch thick, and longitudinal strength of hull is obtained by bracing carried up from two side inner keelsons or girders and tied at the main and upper decks, Fig. 3. This bracing consists of verticals intersected by diagonals, the aftermost of which supports the stern girder that carries the main shaft bearing-blocks. The bracing or truss-work also carries the upper deck and supports the wooden awning, besides forming the side stanchions to both the main and upper decks which it encloses. These decks are of light teak scantling and are left quite clear for passengers and goods. The steering-gear consists of two rudders of a form to suit the vessel's stern, the tillers being on the upper deck and worked by hand-gear from forward.

The engines are of the locomotive type, having two high-pressure cylinders working at 160 lbs. pressure per square inch and exhausting back through the up-take. The cylinders are firmly secured to the upper flanges of steel joists (supported by brackets on the stern) which form the engine-seating and carry the bearings of the shaft. The feed-pumps are independent of the main engine, and consist of two Worthington pumps working horizontally under the boiler, one of them being sufficient to maintain a good feed. In shallow-draught vessels of this kind trouble is invariably met with in the suctions of feed- or circulating-pumps when the vessel is under way. With the ordinary rose-plate or shield fitted at the bilge or bottom and immersed only about 12 inches, the pressure is insufficient to overcome the velocity of the flow of water at the surface of the rose-plate when going at a fair speed, and the pumps refuse duty. The Author has found that the only effectual way to overcome this is to fit a cup-shaped rose with an orifice set to catch the water when the boat is under way.

The wheel is of the ordinary radial type, 10 feet in diameter, with floats that can be reefed at varying draughts.

The vessel described has a boiler of the locomotive type with the ratio, grate- to heating-surface, of 1 to 25·6; a second vessel, now in course of construction, will have a Thornycroft water-tube boiler. It is noteworthy that although the latter boiler has larger grate- and heating-surfaces, it is more than 2 tons lighter than the locomotive type of boiler; and it will be a matter of interest to compare the working results of the two. This water-tube boiler will be the first of its kind used for river-work in

India; and the two important points that will be looked for are its behaviour when fed with the muddy waters of the shallow rivers, and its suitability for being left in charge of native engine-drivers and firemen.

It was specified that the boilers should be of such construction as to obtain a Board of Trade certificate, as passenger-carrying vessels in Bengal are surveyed by the Board. The makers of both types complain of the trouble they have had to secure this, and it is thought that the Board of Trade rules would bear some revision in this respect. The Author considers that fresh rules for small locomotive type and water-tube boilers might be introduced. In this instance, the locomotive type of boiler is far heavier than if it had been built according to the practice of the best makers of such boilers; and it is improper that such practice should be subject to rules specially adapted to the case of the heavy marine type of boiler. Notwithstanding this extra weight of boiler and of additional fittings and woodwork for the accommodation of European passengers, the first of these small vessels, when equipped with stores, a full native crew and 3½ tons of coal, attained, with a draught of 17 inches, which is rather more than she was designed for, a mean speed of 10·4 miles per hour. The vessel showed good manœuvring powers and was easily handled. The simplicity in working, together with the accessibility of all the working parts, are noticeable features. When running quite light with midship holds and decks empty, a certain amount of vibration might have been expected, the weights being distributed at the extreme ends of the hull and the truss-work being in tension; but with the wheel-floats kept at the right degree of immersion not the slightest vibration was apparent. To the simple method of stiffening the hull are due the advantages possessed by stern-wheel vessels over the side-wheel or screw type for light draughts. Another appreciable advantage of the stern-wheel over the screw-propelled vessel is that the wheel, if damaged, can be repaired without docking or slipping.

For the design of the main-line despatch vessel, Figs. 4, 5 and 6, Plate 6, results obtained from several types of that class at present in use, together with experience gained in their working, were utilized. The principal requirements are: (1) A speed of 15 miles per hour, as these vessels carry the mails for the Government and run under contract according to a time-table which may render acceleration necessary in the future; (2) Large emigrant and

native passenger-accommodation, saloon and cabin accommodation for thirty European passengers, and a promenade deck forward.

The dimensions of the hull, the lines of which are shown in Fig. 7, are 200 feet × 24 feet 6 inches × 9 feet, and the deck-area is very large. The upper deck alone can carry 500 emigrants, giving 9 square feet to each passenger, in addition to the saloon and cabin accommodation with the promenade deck forward for first-class European passengers. The main deck is extended to the full width of the sponsons and is overhung and supported from the vessel's sides. The combined area of both decks measured for emigrants and native passengers is 9,408 square feet, and the vessel would carry upwards of 1,000 such passengers. In the sponsons are cabins for the doctor, clerk, second-class passengers, master and engine-driver—besides bathrooms, pantry, native passengers' latrines, cooking-galleys &c. for Europeans and natives, as well as pens and fowl-houses. The outer edge of the main deck is a girder formed of steel angle-bars carrying a teak rubbing-beam which takes the banks, &c., when going alongside. The sponsons are very strongly constructed, the main steel brackets on the ship's side being further supported by diagonal stays from the upper-deck beams. The verticals are formed by the floor-plates, and reverses in wake of the brackets are carried up to the main and the upper decks. The spring-beam is of box section, built of steel plates and angle-bars, and carries on the inside the star centre or eccentric for the paddle-wheel, and on the outside the wooden rubber and four protecting buffers. The hull is strongly constructed of the best Siemens-Martin steel.

The vessel was required to be capable of attaining a maximum speed of 15 miles per hour when equipped with outfit, stores &c., with an allowance of 25 tons for passengers and 60 tons of coal at a draught of 4 feet 4 inches, her deep-load draught being 5 feet.

The displacement at 4 feet 4 inches is 379 tons, and at 5 feet it is 445 tons. The following are the principal weights:—

	Tons.
Weight of hull and metal work about decks	120
Woodwork for decks, cabins and roof	54
Engines and wheels	50
Boiler, with up-take, funnel, and all mountings and fittings	40
Water in boiler	20
Coal	60
Passengers	25
Stores and equipment	10
Total	379

The engines are of the direct-acting compound surface-condensing type, working diagonally on two cranks at right angles, and capable of indicating 600 HP. with a steam-pressure of 120 lbs. per square inch. The cylinders are 22 inches and 43 inches in diameter respectively, with a stroke of 4 feet 6 inches. The entablature-frames are supported on columns secured to the bed-plate, and are tied to the cylinders by diagonal guide-bars of malleable steel. The surface-condenser is constructed of mild steel plates, and is oval in form, with a cooling-surface of 1,000 square feet. The circulating-pump is an independent direct-coupled centrifugal pump. The feathering paddle-wheels are 14 feet in diameter over all, each one having eight floats measuring 9 feet by 2 feet 3 inches. The engines are placed forward of the boiler, which is fired from forward, and the coal-bunkers are formed by the wings on each side. The machinery is kept well beneath the deck, and the engine-hatch allows a clear passage on each side for working the cargo or for passengers. With this object also the paddle-shafts are below deck, and the decks generally are kept clear of obstacles as far as possible. There is a single cylindrical multitubular boiler of large size, with three furnaces and a large heating-surface.

	Square feet.	Ratio.
Grate-surface	70	1 : 27·14
Heating-surface	1,900	

It will be seen that the boiler-power is large for the engines, and this is a point that cannot be too carefully observed for Indian service, where native stoking and country coal are factors that have to be taken specially into account.

The vessel is fitted with steam steering-gear, controlled from the upper deck; also with a powerful steam-windlass forward and a hand-capstan aft. It is lighted throughout by electricity, the installation being of the simplest character. The dynamo and engine, of the direct-coupled type, are placed on deck near the starting-platform of the main engine, with the controlling-valve, switches &c. at hand. The saloon, cabins, engine-room and decks are lighted by single glow lamps of 16 candle-power, the gangways forward and aft of the sponsons being each furnished with a large portable lamp of 80 candle-power.

The Author may remark that on more than one occasion it has been attempted to run these mail-boats at night with the aid of an electric search-light; and he has recently had an opportunity of fitting up and testing in actual practice one of the most modern

types of search-light plant. It consists of a direct-coupled engine and dynamo, running at 360 revolutions per minute with steam-pressure of 100 lbs. per square inch, the output of the dynamo being 50 amperes at 65 volts. The light projected is of 16,000 candle-power. The projector is fixed on deck, and can be set in any direction, the leads being taken through revolving contacts. It is fitted with an ordinary search-light mirror and with a diverging lens specially made to project an arc of light to suit the winding rivers. The whole plant is portable, and can be shifted from one vessel to another. As a result of the trials of this plant, it was found that in the broad rivers, or where it was necessary for the pilot to see the water, the projector caused too great a glare on the water and the light was too intense for purposes of navigation. Where, however, a river is uniform in breadth and the banks are high, or where the channel is marked, the light is of great service in sighting the banks and picking up marks &c., and the plant is now in use on the Upper Cachar waters.

In conclusion, the Author would direct attention to the work performed by despatch vessels of the type described. On the Assam mail service there are sixteen of these vessels running constantly, having one day without steam on each double trip. Once a year they are cleaned and surveyed, and once every four years they are docked for six weeks and overhauled. They run about 320 days in the year, and those who know the wear and tear of fast-running paddle-boats may learn with surprise that, unless the vessels alluded to meet with accident through collision or grounding, they are kept running for four years without any extensive overhaul or repair.

The Paper is accompanied by specifications of the vessels described and by two sheets of tracings from which Plate 6 has been prepared.

(*Paper No. 2719.*)

"The Filtration of the Müggel Lake Water-Supply, Berlin."

By the late HENRY GILL, M. Inst. C.E.

THE population of Berlin, within the municipal boundaries, which enclose an area of 24·3 square miles, was, at the close of 1892, about 1,610,000. In the year 1856, when the first water-works were constructed for the supply of the city, the population did not exceed 400,000. These works, built on the right bank of the River Spree, where it enters the municipal boundary, were gradually enlarged until, at the close of the year 1873 when the municipality purchased them, they were capable of supplying Berlin with 13,200,000 gallons of filtered water in twenty-four hours. They only sufficed to supply part of the city, so that the municipality, soon after taking possession of them, proceeded to construct new works about 7½ miles to the north-west of the city on Lake Tegel, an enlargement of the River Havel, in accordance with plans submitted by the Author. These works can send into Berlin 19,000,000 gallons of water in twenty-four hours. They were commenced in 1874, and, after an interval of five years between the construction of each half, were completed in 1887.[1] In that year it became evident that, with a yearly increase of the population of the city of 3½ per cent. of that of the preceding year, *i.e.*, from 40,000 to 45,000 per annum, new waterworks would be required before the close of the year 1892, in order to prevent interruption of the normal water-supply to the inhabitants.

The Havel, at the Spandau weir and lock, immediately below which the Spree and Havel unite, has a minimum rate of discharge of 1,760 gallons per second. The Lake Tegel works above the weir at Spandau take from the lake 220 gallons per second; and since a doubt existed whether the Government, and more especially the military authorities, would sanction the diversion of a larger quantity for the purposes of Berlin, it was decided to locate the

[1] Minutes of Proceedings Inst. C.E., vol. cvii. p. 210.

new works to the east of the city on the upper reaches of the River Spree, at a point where the water was not, nor was likely within a measurable period to be, affected by manufacturing industries or by river traffic.

The most suitable site was found to lie on the northern shore of the Lake Müggel about 4 miles above the town of Köpnick, and 1 mile above the outfall of the Spree, at a place about 12 miles distant in a direct line from the heart of Berlin. At Köpnick the Spree divides, the northern branch retaining the name of Spree, and the southern taking that of Dahme. The minimum rate of discharge of Spree and Dahme at the fork at Köpnick is 2,861 gallons per second, of which 2,179 gallons per second flow out of Lake Müggel. Since the enlargement of the Spree-Oder Canal, the very considerable river traffic from the iron and coal districts of Silesia and of the Oder Basin has been diverted for a stretch of 16 miles above Köpnick from the main river, and passes down the Dahme, thus avoiding Lake Müggel. This lake, in the midst of a pine forest, is oval in form, and is 2·9 miles long from the entrance of the Spree at the east to its outfall at the west, and 1·43 mile broad. The depth which obtains over the greater part of its area is 26½ feet, and the quantity of water it contains is about 8,859 millions of gallons.

Plans and estimates for raising from this lake, filtering, and pumping to Berlin 39,400,000 gallons of water in twenty-four hours were prepared by the Author and were passed unaltered by the municipality in 1888. The sanction of the Government to the project was coupled with the condition that on the completion of the new works the original waterworks of 1856 should be abandoned. Of the 39,400,000 gallons 1,330,000 gallons are required for steam and condensation water at the works for distribution at Lichtenberg and Belforter Strasse. The project assumed that the 38,070,000 gallons from Lake Müggel and the 19,000,000 from Lake Tegel, amounting in all to 57,070,000 gallons, would suffice to supply a population of 2,500,000 with 22·83 gallons of water per head on the day of maximum consumption. In consequence of there being no ground in the immediate neighbourhood of Berlin sufficiently high to enable the city to be supplied direct from reservoirs built on the plateau on either side of the valley of the Spree, the water-supply is dependent upon the continuous action of pumping engines. In consequence of the city having extended up the plateau, the distribution pipes have been divided into two zones. The supply is constant, and house cisterns may be said not to exist. The water is sold exclusively by measure, each house-block having as a rule

but one water-meter.[1] A daily record has been kept, from the earliest period, of the quantity of water sent daily into the city. Appendix I. gives a statement of the average and the maximum quantity supplied to the entire city and to the upper zone of the pipe-system during thirteen years.

The reservoirs on the plateau at the Belforter Strasse works have hitherto been fed (uneconomically) from the pipe-system of the lower zone, so that the Table for the upper zone alone is of value for ascertaining the ratio between the maximum consumption and the daily consumption on the average of the year. The Table shows that on the average of the thirteen years this ratio has been as 143 to 100. Appendix II. shows what this ratio is in twenty-seven German cities which supply water on the same system and under the same circumstances as exist at Berlin. The average of the twenty-one cities shows a ratio between the maximum day's supply and the daily supply on the average of the year to be as 149 to 100. As soon, therefore, as the mean supply per head per day on the average of the year has been fixed, after study of the local circumstances to be met in each case, the Table affords a guide for ascertaining the quantity necessary on the day of maximum consumption, an essential factor in determining the magnitude of the works. In addition to the record of the daily supply, Berlin has, for a long series of years, for one week in each month, kept a record of the quantity of water sent daily into the city in each of the twenty-four hours. A specimen record—that for 13th August, 1892—is given in Appendix III. From the results of these observations it appears that the maximum consumption of one hour as compared with the average consumption of the twenty-four hours varies within very narrow limits. Observations for Breslau and Hanover, cities supplying water under similar conditions to those at Berlin, show that the above-mentioned law applies there also.

It is evident that these factors serve to determine the magnitude of the pumping engines for the distribution, which, in cases where house-cisterns do not exist, must accommodate themselves to the varying demands of each hour; and also the magnitude of the pipes for distribution from these engines to the pipe-system within the city. The Tables give also the basis for the determination of the minimum capacity of the service-reservoirs, from which the above-mentioned engines obtain their supply; or from which, when the town is supplied without the intervention of engines,

[1] Minutes of Proceedings Inst. C.E., vol. cvii. p. 203.

the supply is taken direct. This capacity is evidently that percentage of the total supply of the twenty-four hours given at the foot of columns 4 and 5 in Appendix III. The results of these Tables have been used in determining the magnitude of the various structures of the Müggel-Lichtenberg Waterworks of Berlin.

Preliminary Investigations.

Before commencing the description of the Müggel-Lichtenberg Works, of which the filters form a prominent feature, it is advisable to refer to the quality of the water, the climate and the results of investigations with reference to the filtration of Spree water, which have contributed to determine the peculiarities of the filters and the system of working them.

Chemical Analysis of the Spree Water.

	Grains per Gallon.
Residue after evaporation at 110° C.	9·81
Residue after cineration at 110° C.	7·57
Loss by cineration	2·24
Lime, CaO	3·54
Chlorine	1·25
Sulphates	0·95
Nitrates	0·00
Nitrites	0·00
Ammonia	traces
Organic Substances—	
Consumption of permanganate of potash, $KMnO_4$	1·94
Oxygen	0·48
Degrees of hardness, soap test	6·10

From this analysis it appears that the river water is soft and rich in organic substances. The presence of these is due to the swamps and marshes of the Spreewald. Even in winter this water requires careful filtration. The period of frost commences in Berlin about the middle of November and may last till the end of March. A break in the frost, with a temperature above freezing-point during twenty-four hours, seldom takes place for a sufficient number of days to enable the ice, which on open filters forms to the thickness of 15 inches and more, to be cleared away, and the filter cleaned. The Berlin filters, except those built in 1854–56, are therefore necessarily vaulted over and protected by a covering of earth.

For many years after the introduction of sand-filtration by James

Simpson, the operation was considered to be solely a mechanical process for sifting out visible matter in suspension, the results being tested merely by the eye. Subsequently the aid of chemical analysis was used to determine the amount of change produced in the quality of the water by passage through the filter material. The two methods of test gradually led to a reduction of the speed of filtration, in the best regulated works, to a rate of percolation vertically through the sand of 4 to 6 inches of water per hour. Nevertheless up to 1880 the necessity for some mechanical arrangement to ensure that each filter during its whole period of service delivered at the rate found to be the most suitable for the water of the particular source of supply, and that no filter of the battery in action exceeded this rate, does not seem to have been recognised. When, however, in 1883 Dr. Robert Koch, as chief of the Hygienic Institution of the University of Berlin, published and taught bacteriology and its application, amongst other things, to the testing of water, a clear conception of the process of sand-filtration and the cause of the changes it produced could be arrived at. At this period the Hygienic Institution of the University of Berlin was appointed to test, at fortnightly intervals, the water supplied to the capital; and the municipality, at the suggestion of the Author, caused the engineer in charge of the Stralauer Works to go through a course of instruction, and at the same time to have the pumping-station fitted out with a laboratory and apparatus for bacteriological investigations. On the conclusion of the course, this engineer—Mr. Piefke, a skilled chemist—commenced a series of investigations on sand-filtration under the supervision of Dr. Koch. The results of these labours were laid before the waterworks authorities in a report dated the 15th of April, 1887, which was published in the same year.[1]

The sand of the Berlin filters, after sifting and careful washing, is of fairly uniform grain of from $\frac{1}{2}$ to $\frac{3}{4}$ millimetre diameter. The volume of the interstices is, on an average, 33 per cent. of the whole mass. It consists of about 81 per cent. of quartz, 2·3 per cent. of carbonate of lime, and 16·7 per cent. of felspar and silicates. Although the water of the Spree abounds in micro-organisms, no pathogenic bacteria, such as the bacilli of cholera, typhus, or tuberculosis, have as yet been found in it. These latter, when fully developed, vary in length between $\frac{1}{600}$ and $\frac{1}{300}$ millimetre, whereas

[1] "Die Principien der Reinwasser Gewinnung vermittelst Filtration." Berlin, 1887.

the harmless bacteria which abound reach the length of $\frac{1}{200}$ millimetre. It is desirable, in the interest of health, to remove as many bacteria as possible from the water before its use for household purposes. The filter-sand, even when most closely packed, has interstices between the grains of more than $\frac{1}{10}$ millimetre. Micro-organisms of the above infinitesimal size, therefore, pass readily through the zigzag channels between the sand-grains, and may easily escape detention by contact with the grains forming the walls. The longer the channels—that is, the greater the thickness of the sand-layer—and the slower the rate of passage, the greater the probability of the bacteria coming into contact with, and being detained by, the sand-grains. Here, however, economic considerations limit both the depth of sand-layer and the speed—more especially where the filters must be covered—so that in practice the thickness of the sand-layer varies between 2 and 3 feet, and the speed can seldom be less than 4 inches per hour. The same considerations exclude the use of very fine sand, which necessitates an increased head of water, and thus causes an injurious pressure on the upper sand surface.

Notwithstanding, however, the above considerations, sand-filtration, properly conducted, does succeed in preventing, to a very large extent, the passage of the bacteria through the sand-layer. Investigation proved, contrary to all anticipation, that, for the Berlin water, sand which had been many years used for filtration yielded much superior water to sand which had not been previously used for that purpose. The condition of the former, after ten years' use in a covered filter, was investigated by the gelatine process. One hundred grams of sand were shaken in 100 litres of sterilised water in stoppered bottles for ten minutes. One cubic centimetre of this water was then diluted with 100 litres of sterilised water, and of this 1 cubic centimetre was poured on the gelatine, and Koch's process then followed. The result was that in 1 kilogram of sand, taken from a filter just cleansed and prepared for further service, there were found:—

	Colonies of Bacteria capable of further Development.
	Millions.
At the surface	734
„ 4 inches beneath the surface	190
„ 8 „ „ „	150
„ 12 „ „ „	92
„ 24 „ „ „	60

The above numbers are the mean results of six careful repetitions of the experiment.

The washed sand, apparently perfectly clean and causing no turbidity when stirred in a glass of water, felt, however, no longer sharp. Examined under the microscope, it was found that all the grains had become enveloped in a thin skin, easily destroyed by heat. That this skin consisted in part of bacteria or germs was proved by a further bacteriological examination. One hundred grams of this apparently clean sand was treated twice as described and the water of the third dilution was tested, when it was found that nine millions of colonies per kilogram of sand were still present. Nor could the sand be entirely freed from the coating by six repetitions of the washing.

It was now assumed that, by filtering through a thick layer of sterilised sand, water of a better quality would be obtained than by filtering through sand coated with bacteria. A circular sheet-iron filter, carefully sterilised, was then filled with a $1\frac{1}{2}$ metre deep layer of sand, sterilised by exposure to a temperature of 200° C., and charged from beneath with sterilised water. It was then fed from above with Spree water, and started at a speed of 10 centimetres percolation of water per hour. This speed was kept unvaried till the head necessary to maintain it had increased up to 80 centimetres. It was then emptied, the deposit removed, and the filter started afresh at the same speed, and this operation repeated four times. During these periods the unfiltered- and the filtered-water were examined bacteriologically at intervals of two and, later, of four days. The result was quite unexpected, inasmuch as the filtered-water contained in every case more bacteria than the unfiltered-water. Towards the close of the fifth period, however, the filtered-water showed fewer colonies than the feed-water contained. It was evident that new generations of micro-organisms were produced during the passage of the water through the sand, and could not during this period be detained in the channels between the sand-grains. At the close of the fourth period the sand was removed from the filter and examined. It was found that for its whole depth the grains had become slightly coated with a slimy substance (zoogene). The sand was returned to the filter and the filtration carried on under the same conditions. Some months, however, elapsed before the filter yielded water of a quality at all comparable with that from the old filters of the works. The results were so unexpected that several similar filters were set in action under precisely similar conditions to test the accuracy of the first experiment. All, however, confirmed the accuracy of the results of the first trial filter. Other filters with much finer sand were then tried under precisely similar condi-

tions; the results, however, remained the same. The effect of filtering through deep layers of "ripe"[1] carefully-washed sand of the filters of the works was tried; but no improvement was found to result from the use of a deeper layer than 60 centimetres.

These chemical and bacteriological investigations, continued for more than two years, under favourable circumstances as to their extent and range, and under the guidance of the Hygienic Institution of the Berlin University, prove that the effect of sand-filtration on river and lake waters, in which micro-organisms abound, is due in but a slight degree to chemical action, and almost exclusively to the labours of the bacteria. The chemical reaction cannot but be small, since with a sand-layer of 24 inches in thickness and with water-passages 33 per cent. of the mass, the water, when passing through it at a rate of 4 inches vertically per hour, remains scarcely two hours in contact with the sand—a period far too short for the oxygen of the air and of the free carbonic acid, both contained in small quantities in the water, to act with appreciable effect on the granite, limestone, and silicate grains of the sand. The sand in itself, under the circumstances described, almost neutral, is merely a matrix in which the bacteria bed themselves, multiply and perish, thus causing the slimy coating of the sand-grains. Adhering to this and held fast by it, in so far as the water streaming through the grain-channels is insufficient in force to wash them away, the bacteria carry on by consumption the nitrification—the conversion of the organic substances liable to putrefaction in the water into inorganic matter. Sand-filtration is therefore in the main a biological process. The many small particles of matter which (in addition to the bacteria, whose presence is never wanting where putrefying matter is found) are contained in river and lake water, and which cause turbidity, deposit themselves on the surface of the sand and soon form a continuous covering, the pores of which are very much smaller than those between the grains of fine sand. This is more particularly the case when this covering consists of plastic loam or clay. An equally efficient coating is produced by the algæ and especially by the diatoms which abound in river and lake waters. Through this coating the water percolates, on it and in it the bacteria settle, reinforced in number by each drop of water which passes through. Multitudes of the micro-organisms pass also with the water through this deposit on to the surface and into the sand, which, if ripe, presents a suitable surface for their detention.

[1] That is, furnished with the characteristic glutinous coating (zoogene).

To this they adhere and continue their labours on the water passing them. The colonies are most dense at the surface of the sand where the food-supply is most abundant. The relative density of population of the sand-zones, from the surface downwards, has been given above.

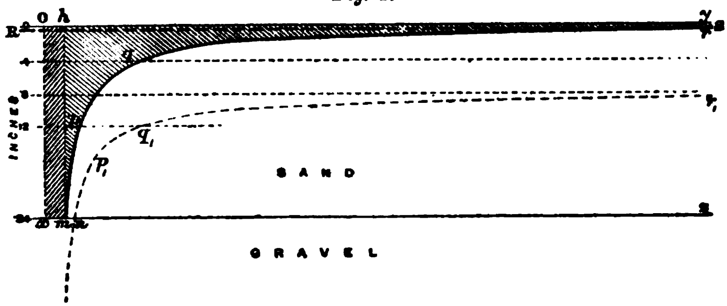
After careful washing, a kilogram of the cleaned sand still contained from 50,000,000 to 60,000,000 of bacteria adhering to the grains, nor could a diminution of the number to less than 6,000,000 be obtained by six repetitions of the washing process. Sand of such a degree of cleanliness is almost as inefficient for filtration purposes as sterilised sand, and in fact old sand with a bacteria coating, yielding about 58,000,000 to 60,000,000 of bacteria colonies to a kilogram of sand, gives, for the lake and river waters about Berlin, the best results.

The removal of the organic matter from the water, that is, the conversion of it into inorganic matter by the labours of the bacteria, takes place with greatest intensity at the sand-surface, where these organisms most abound, and diminishes in intensity in each layer beneath in proportion to the number of labourers at work. On testing the water taken from a trial filter, with a sand-layer of 6·56 feet in thickness, at various depths beneath the sand-surface, by means of permanganate of potash, it was found that the chemical effect had been most powerful in the layers down to a depth of 12 inches; that beneath this to the bottom the reduction of the oxidation was exceedingly small. This shows that the change in the quality of the water was produced in those layers where the bacteria were to be counted by hundreds of millions. It appeared in fact that in the lower sand-strata there was insufficient food to support a large bacteria population. From this it may be deduced that no advantage commensurate with the great increase of cost is gained by an increase in the thickness of the sand-layer.

Since the bacteria are liable to be washed downwards by a stream of greater force than that which prevailed when they came into contact with the sand-grains, it is of the utmost importance to avoid an increase of speed, especially a sudden increase. Mechanical arrangements must be adopted to prevent this, and it must be impossible that any filter in action can in any way affect the yield of the neighbouring filter. The chief cleansing action takes place in the mud deposit on the surface of the sand, and in the sand immediately at the surface. In this region the coating of deposit is soft, and with its dense population requires careful and tender treatment to avoid squeezing out the bacteria

by undue pressure. It is obvious that as soon as an appreciable deposit has taken place on the sand-surface, any increase of "head" must be chiefly caused by the layer of this deposit. If the sand beneath is not absolutely homogeneous, as it cannot be, any increase of pressure may cause a depression and a tearing of the mud-skin on the less dense parts of the surface of the sand. Through such a rupture the bacteria are at once washed, by the increased local current which ensues, into the sand beneath, and may be carried through the entire layer. Too great a pressure must therefore be avoided. Yet a gradual increase of pressure must of necessity take place, when the yield is to be constant, in order to overcome the increasing friction of the passage of the water through the filtering medium, in proportion as its interstices become gradually closed by the deposit. Nor is such increase, if gradual, injurious provided certain limits be not exceeded. With the lake and river water around Berlin experience has proved

Fig. 1.



that the maximum permissible difference of level of the water surface over the sand and the water-surface at the discharge is about 2 feet.

It has been stated above that the number of bacteria colonies is greatest at the surface of the sand and decreases very rapidly in successive layers beneath. In *Fig. 1* O *x z y* represents the 2-foot deep sand-layer of a filter. If with O as origin, and distances along O *x* representing depths of sand-layer, and those along O *y* numbers of bacteria colonies per kilogram of sand, the 60,000,000 bacteria colonies per kilogram of the ripe sand be plotted at each of the depths 0, 4, 8, 12 and 24 inches, the line *h m* parallel to O *x* is arrived at. The hatched strip O *x m h* then represents the ripe condition of filter-sand after long use, in which condition a powerful water-current and attrition of the grains against each other fail to free them from the bacteria. If now with the same abscissas,

the 734, 190, 92, and 60 millions be plotted as ordinates, the curve *m p q r* is arrived at. This curve exhibits pictorially the density of the bacteria colonies in the various layers of a sand-filter at the close of a period of service when it gives the best results. By the process of cleaning, the thickness of the sand-layer is reduced by the removal of the layer O *y* S R. If this process is repeated till the normal thickness of the sand-layer is reduced by 8 inches, the curve *m p q r* will have descended and taken the position of the curve $n p_1 q_1 r_1$. A further reduction of the thickness of the sand-layer is not advisable, inasmuch as the sand at its lower surface, *x z*, will have become colonised by the amount *m n* more than the amount *x m*, and the colonies in *m n* are liable to be washed through into the gravel and filtered-water reservoir. The normal level of the sand must, therefore, be reinstated by a filling of 8 inches of washed ripe sand from the depôt. At this stage, and until the newly-filled sand has become more densely colonised at its surface, the filter must give less satisfactory results than previously. To a minor degree this takes place after each cleansing. With the lake and river water of Berlin it is advisable in every case, on restarting a filter, to let it remain inactive for twenty-four hours after being filled, in order to allow of sedimentation. If the filter has been merely cleaned, it will deliver, at its normal speed, satisfactory water on the third day, provided the progress from the start up to this speed is gradual. If, however, the filter has received a fresh layer of sand, the normal speed must not be reached before the lapse of ten days.

The question naturally suggests itself here—Is it necessary in constructing filters to wash the filtering material? The reply is that the gravel or other very porous material, which is merely a scaffolding supporting the layer of sand, must be carefully freed from all matter subject to putrefaction. Unless this be done, the relatively few bacteria which escape through the sand into this substratum would find food on the uncleansed surfaces, settle there and multiply. If, however, the substratum has been freed from all matters subject to putrefaction, the few bacteria washed through pass on without increase. The results of the above investigations have been embodied in the instructions for the management of the Lake Müggel filters given in Appendix IV. As regards the structure of the filters, their number and the reserve area, the investigations led to the project now to be described.

Müggel Lake Filtration Works.

The filtration works are situated on the north shore of the Müggel Lake, 1 mile above the outfall of the Spree at a point where the deep water approaches most closely to the shore. The work of the pumps at this station is constant. The water is raised to the Lichtenberg service-reservoirs, 10 miles distant, on the highest point of the plateau to the north-east, and 3 to 4 miles distant from the centre of Berlin. From these reservoirs the water is raised by one set of engines into the pipe-system of the lower zone of the city, by a second set of engines into the service-reservoirs of the previously mentioned pumping-station at Belforter Strasse, within the circular railway, and by a third set of pumping-plant direct into the pipe-system on the plateau outside the circular railway.

When the project as above described is carried out and in full action, the Lichtenberg Works, after having disposed of the 1⅓ million of gallons required for steam and condensation, will in twenty-four hours lift and distribute in the two pipe-systems on the plateau 10,760,000 gallons for the supply of 471,000 people, and 27,310,000 gallons into the pipe-system of the lower zone for the supply of 1,195,666 people. It may be mentioned here that this pipe-system is common to the Müggel-Lichtenberg and Tegel-Charlottenburg Works, and that the latter delivered in twenty-four hours 19,000,000 gallons for the supply of 833,333 people.

In order to prevent as far as possible an interruption of the supply of the city by the failure of any part of the works, for the filtration of the water at the Lake Müggel, its transport to the auxiliary station, Lichtenberg, and its further lift there and ultimate distribution, they have been divided up into four equal parts, each with its reserves, independent of, yet capable of combined action with, any one or all of the others. An exception to this principle has been made only with reference to the main conduits connecting the Müggel with the Lichtenberg stations. Here, from motives of economy and because these conduits are not subjected to sudden shocks from variation in pressure, instead of four, two cast-iron main pipes of 47·24 inches internal diameter have been provided. For the Lake Müggel Works an area of 81·6 acres of forest land with a water front of 1,404 feet has been purchased from the Government. On this, four independent engine-, boiler- and coal-houses will stand, two of which are completed and in action. A massive quay-wall at the lake forms

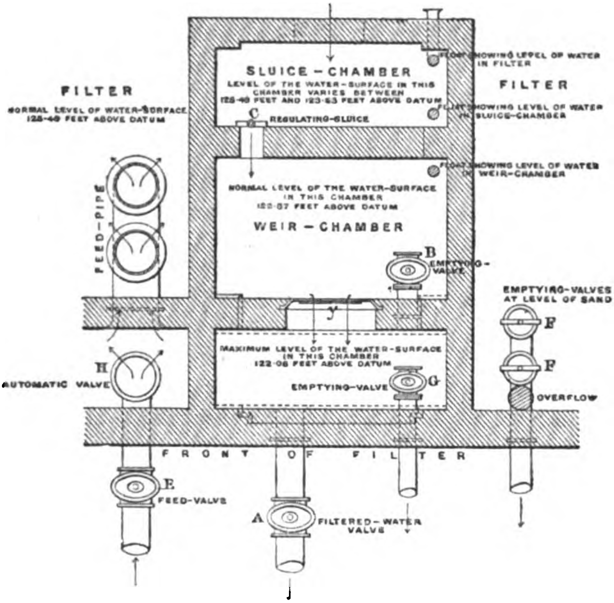
the water boundary. The Government has, by the deepening and regulation of the Spree through Berlin down to its junction with the Havel, and by the new weir just completed in the heart of the city, ensured that the depth of the upper water and of that of the Lake Müggel will in future not vary more than 2·3 feet. In front of the quay-wall the lake has been dredged to a uniform depth of 6·6 feet at normal water-level for a distance of 394 feet from the shore. At this distance the bed of the lake falls with a steep slope to a depth of 26½ feet. From this distance from the shore the water flows to each engine-house, through an oak conduit 4·92 feet square, or 24·21 square feet sectional area laid with its upper surface at the level of the bed of the lake, that is, 6·6 feet beneath normal water-level. Each oak conduit ends at the quay-wall in a small chamber in which an iron grating stops the further progress of larger floating matter. From this chamber the water passes by a brick culvert into the straining-chamber 62½ feet long and 9 feet broad. This is separated into two divisions by a framework of iron into which vertical screens of fine copper wire are inserted. The grooves into which each panel is slipped from above are double, so that when cleaning or repair is necessary a reserve panel can be inserted either before or behind the panel which must be removed. This screen stops the further progress of fine floating matter. From the land side of this screen a cast-iron pipe of 35·83 inches diameter, commanded by a sluice-cock, in each case conveys the water into the sump of one of the single-acting plunger pumps, actuated by one cylinder of the vertical compound high-pressure condensing engine. Although the Müggel Works have only to deliver 440 gallons per second into Berlin, these engines in addition must lift from the lake water for the service of the filters for washing the filter-sand, for steam and condensation for the large engines which lift the water to the Lichtenberg station, for steam and condensation of the engine of these works and also for the same purposes for the Belforter Strasse pumping-station. Each of the filter-supply engines, of which there are six completed, three in each house (one engine in each case being in reserve), can lift 249,470 gallons per hour.

At the eastern end of the quay-wall a pile-work harbour has been constructed for the protection of the coal-barges. This is essential, inasmuch as on account of the breadth of the lake, 1·43 mile, a moderate wind raises waves dangerous for open barges that are almost without freeboard.

Filters.—At present only two of the four independent groups of filters and engine-houses are completed, Figs. 3, 4, 5 and 6, Plate 7.

Each group has to filter and pump 9,850,000 gallons in twenty-four hours. The work of each group is constant. The maximum speed of filtration is fixed at 2·04 gallons per square foot per hour. There must therefore be an active sand-surface of 4·608 acres. This surface is divided up into eight basins of 0·576 acre sand-surface. In order that the proper emptying, cleaning, recharging with sand, refilling and gradual starting of the filters may be accomplished without affecting the regularity of the discharge at the speed fixed upon, it is necessary, in addition to these eight, to have three reserve basins, so that each independent group

Fig. 2.



Scale 1 inch = 10 feet.

consists of eleven basins with a total sand-surface of 6·336 acres. The eleven basins are arranged, six on one side, and five, together with a small filtered-water reservoir, on the opposite side of a 131-foot broad plateau, beneath and along which the feed- and delivery-pipes as well as the waste-water culvert run. The feed-pipe of each filter-basin is commanded by a screw-cock, but an automatic valve ensures that it is always filled up to overflow level. The discharge from each filter is regulated by an arrangement, *Fig. 2*, and Fig. 5, Plate 7, which ensures, with very small attention on the part of the filter-foreman, that at the outlet a constant

predetermined "head" of water is maintained above a submerged orifice in a thin metal plate, which causes the discharge to be also constant. In the Lake Müggel filters, the level of the water in the weir-chamber, in one wall of which is the submerged rectangular orifice *y*, 2·72 feet by 0·29 foot, is fixed at 2·62 feet beneath the normal water-level in the filter. This maximum charge on the sand is only used in emergencies. In ordinary practice it does not exceed 2 feet. When a filter is started and the sand is free from deposit, a head of 3·6 inches suffices to overcome the friction of the passage of the water through the zigzag channels of the 2-foot thick layer of sand, and about 0·3 inch to overcome that of the passage through the 1-foot layer of gravel; the 1-foot layer of boulders and the walls of the collecting-culvert, in all about 3·9 inches, suffice to cause the delivery of a column of 4 inches of filtered-water per hour.

The adjustment of the filtering-head is effected by causing the filter to deliver first into a sluice-chamber. In the wall separating this from the weir-chamber a sluice is placed, at the level of the floor. When this sluice is closed all discharge is stopped, and the surface of the water in the filter and in the sluice-chamber will be at the same level. On starting the filter by gradually lifting the shutter of the sluice, the prescribed fixed level of water above the submerged orifice in the weir-chamber can readily be attained, the excess of head being absorbed in overcoming the friction through the aperture of the sluice, whilst the difference between the levels of the water in the filter and in the sluice-chamber gives the head required for the predetermined flow. As the deposit on the sand takes place, the resistance to the passage of the water increases and the filtering-head must be increased by lowering the surface of the water in the sluice-chamber without at the same time altering the fixed head above the submerged orifice in the weir-chamber. This is effected by slightly lifting the shutter of the sluice; in the first days of a filter period the slightest lift once in twenty-four hours suffices; in the later days and towards the close, the daily lift necessary rapidly increases. The relative levels of the normal sand-surface of the filters and of the working surface of the water in the small filtered-water reservoirs is so arranged that the filling of the filters from beneath the sand with filtered-water from any of the filter groups can always take place. Should, however, an unexpected demand on the filters occur, neither this nor the condition of any filter can cause any one of the groups to yield more than the predetermined maximum per unit of surface, but would merely produce a fall in

the level of the water in the filtered-water reservoirs. Each of these has an available capacity of about 513,000 gallons, equal to an hour-and-a-quarter's delivery of a filter group. If during such an unexpected demand the filling of an empty filter from beneath be in progress, the necessary head can always be secured for that group by throttling the screw-cock placed on the filtered-water main of each filter group near the filtered-water reservoir.

Comparative estimates of various modes of structure and dimensions for the covered filters proved that, for the circumstances of the case, Gothic vaulting was most economical. It will be seen from the plans and sections that the piers are at an axial distance of 14·37 feet from each other. In addition to the ribs spanned between the piers parallel to the enclosing walls, diagonal ribs spring from pier to pier, permitting at their intersection of an opening in the vaulting of each rectangle for the admission of light. The height of the soffit of each rib parallel to the walls is 5·9 feet above the normal sand-level, which permits free movement in all directions when cleaning the filters, preventing at the same time the contact of the barrows with the piers. The size of the quadrilateral light-openings is such that a direct ray of light falls on every unit of sand-surface. The arrangement of the barrow road entrance to each filter is seen from Figs. 3 and 4. The instructions for the management of the filters are given in Appendix IV.

Sand-washing.—The sand-washing house, with its mud and sand-catch basins, is placed in the middle of the broad plateau between the filters of each group. On the one side is the depôt for dirty sand removed from the filters, on the other the depôt for the washed sand. The floor of these store places, each for about 2,600 cubic yards of sand, is formed of granite slabs set in cement with close joints to prevent the intrusion of worms. In the house is an 8-HP. steam-engine with vertical boiler, which works the sand-washing machines and a centrifugal pump to supply them with water. The construction of the drum of one of these machines is seen in Figs. 8, Plate 7. The engine rotates the drum at the rate of eight turns per minute, and the centrifugal pump furnishes 10 cubic yards of water for each cubic yard of sand washed. The engine lifts the dirty sand from the depôt into the drum, which screws it forward, against a stream supplied at the delivery end and running out at the feed end, to the lift, whence it falls down a sharp incline, washed forward by a second rose-jet into a trough in the house, from which two labourers remove it by shovels on to the granite floor, whence it is barrowed to the store of clean sand. The dirty water from the weir at the feed end of

the drum runs off into the mud-settling basin, from which it escapes by means of a long weir. The mud deposit in this catch basin is almost solely organic matter, and, after a year's wintering, is used as manure for the sward covering of the filters. The fine sand, useless for filtration, carried over a small weir at the trough at the delivery end of the drum, falls by a separate channel into a small covered sand-catch basin from which the water escapes into the waste-water culvert; also over a long weir, thus ensuring the culvert against deposit.

Filtered-water Reservoirs.—The arrangement of the filtered-water reservoir of each group is seen in Fig. 7, Plate 7; it is such as to prevent a stagnation of the water at any part of its passage from the entrance to the exit. All the structures at Lake Müggel stand on sand. The walls of the filters and reservoirs, built of clinkers in cement, are founded on puddle concrete. The clay is ground in a mill, forced through a press, and on issuing is cut into slabs 4 inches thick. A layer of such slabs forms the lowest course. On it 4 inches of granite road metal is spread and rammed through the clay to the sand. A layer of clay slabs follows, on which again 4 inches of granite road metal is spread and rammed through the clay till it rests on the stones beneath; this process is repeated till a compact layer of 12 inches is formed. The spread of the foundations is such that the pressure on the concrete under all walls is as nearly as possible equal to 22 lbs. per square inch. The floors are made watertight by a layer of puddle 15·75 inches thick prepared as above and rammed in four layers. On this rests 6 inches of cement concrete (1 : 6), and it is finished off by a 2-inch layer of cement plaster rubbed smooth. The backs of the walls are made water-tight by a sheet of similar puddle from 12 to 16 inches thick. The backing of the vaulting is of cement concrete covered, as are the vaults, with a 2-inch layer of cement plaster, on which rests 2 feet 6 inches of earth. The drainage from this falls through four clay tubes at each pier into the unfiltered-water of the filters. At the reservoirs this water is led off at the end walls of the vaults. The filtered-water from the reservoir of each filter-group flows into a small reservoir at the pump end of the engine-house of the group. In this house are three engines, one of which is a reserve. Each acting engine lifts 205,200 gallons of filtered-water per hour into the 10 miles distant service reservoirs of the Lichtenberg Works. The suction-pipe of these high-speed engines is short and of ample diameter, and beneath the suction-valves of each pump an air-vessel of large capacity is connected.

In the engine-house, on the pressure main of each engine, stands an air-vessel of 124 cubic feet capacity, or sixteen times the displacement of the plunger of the double-acting pump. The pump-valves are ring valves which open automatically, but are closed by the engine by means of special mechanism. The waste water of the Müggel Works is not discharged into the lake, but flows through an egg-shaped culvert, 4·9 feet high and 1⅛ mile long, into the Spree, 820 feet below the outfall of the river from the lake.

Conduits and Distribution System.

The Lake Müggel Works are connected by a branch with the Silesian Railway which passes close to the northern boundary of the works. The cast-iron pipes of the two conduits connecting the Müggel and Lichtenberg Works have an internal diameter of 47·24 inches and a length of 10·07 miles. It was necessary to deviate from the straight line between these works in order to avoid the low-lying swamps, whose surface is but little raised above the water-level of the permanently saturated underground, and to strike at once for the plateau. Although their length is thus increased, the pipes are brought as soon as possible near to the level of the hydraulic gradient, enabling thin walled pipes to be used for two-thirds of the entire distance. Public roads have been avoided; only in one case, for a distance of 0·56 mile, has a public highway been used. For the pipe-line a strip of land 33 feet broad has been purchased. The configuration of the country crossed is such that the line has been subdivided into five districts with a shut-off and shunt arrangement into the neighbouring pipe line, as well as emptying-cocks at each of the five water-courses and automatic air-valves at each summit. Although at present only one line of pipe has been laid, the above arrangements have been carried out for the double line to prevent future interruption of the supply. No screw-cocks of a larger diameter than 35·83 inches have been used. Experiment has proved that in pipe-lines of 36 and 48 inches diameter the insertion of a screw-cock (with appropriate conical approach and exit connections), which contracts the area by 50 per cent., requires but a slight increase of head, in each case less than ¾ inch, to maintain the normal delivery. The first turns of the spindle of a closed cock raises the nut of the spindle without lifting the door, thereby establishing a connection with sectional-area equal to a 4-inch pipe, between the charged and empty sides of the pipe-line. The manufacture of the pipes was watched in each foundry by qualified inspectors. The pipes remained five hours in the moulds to ensure gradual cooling, and

were tested with mineral oil to a pressure of ten atmospheres. The pipe-lines cross under the embankments of two State railways, in brick culverts. The lines also cross the Dahlwitz Muenchehofer morass by a pile structure 312 feet long, at the most favourable point where, however, firm sand in the deepest part was first found at a depth of 51 feet beneath the surface. Since this morass can seldom be crossed on foot, a traveller has been constructed to run on rails on the structure, and is kept in a corrugated-iron shed at one extremity.

Lichtenberg and Belforter Strasse Works.—The Lichtenberg Works are built on a site 29·37 acres in area, with a frontage on the high road from Berlin to Alt Landsberg of 2,122 feet. Here also the subdivision of the works into four equal and independent parts has been maintained, of which at present only two have been completed. The Berlin records prove that for that city an available reservoir capacity of one-fifth of the water quantity necessary during the twenty-four hours of maximum consumption would suffice for the service-reservoirs. To these reservoirs a capacity of one-fourth of this maximum, exclusive of the reserve about to be mentioned, has been given in two independent structures, one for each completed quarter of the entire scheme. Each reservoir is divided by a middle wall into two equal and independent parts. The sum of the available water contents of three of the four divisions has been made equal to the fourth part of the quantity required on the day of maximum consumption, so that the fourth division forms a reserve to enable repairs of the structures or their connections and occasional cleansing to be carried out. When, therefore, the four reservoirs are in action, which in practice is often the case, the available water contents of the service-reservoirs is one-third of the demand on the day of the maximum consumption. The available water-contents of each one of the four divisions is 1,641,500 gallons. The ground of the site is a compact loam with many sand-filled fissures. A slight rainfall converts the loam into sludge. The enclosing and internal walls supporting the arching are founded on cement-concrete. The floor between the internal walls is puddled and rendered watertight in the same manner as the floors of the Müggel filters. The enclosing walls are also backed with puddle. The arches are covered with asphalted felt sheets, on which a 4-inch layer of sand is spread, which is overlaid by 30 inches of loam and turf.

On account of the sand-veins in the loam under the Lichtenberg Works it was found necessary, in order to prevent the floors of an empty reservoir division, or of the condensation water-cooling pond,

from being lifted by the hydraulic pressure of the water in the fissures of the loam, to surround these structures with a drainage system laid deeper than their foundations. This system delivers into a main egg-shaped culvert 4·97 feet high, laid with a fall of 1 in 3,000, into a water-course passing close to the eastern boundary of the works.

The openings in the walls supporting the arches are so arranged that the water cannot stagnate in any part of its flow from entrance to exit. An open condensation water-cooling pond of 328,230 gallons capacity is provided for the six steam-engines of the two subdivisions now completed. Six engines, three in each house, one of which is in reserve in each case, raise the water from the reservoirs to a height of about 98 feet into the lower zone of the pipe-system of the city. The supply being constant, these engines must satisfy the varying demands of the city as it fluctuates. The pumps and steam cylinders are, therefore, so designed that they can raise in each unit of time 51 per cent. more than the average supply of the twenty-four hours on the day of maximum consumption of water.

The diameter of the delivery main for the lower zone is 47·24 inches for 1⅓ mile. As soon as it crosses the Circular Railway it divides out into three lines of 35·83 inches diameter, and these into five 30 inches in diameter, forming junctions at five places with the 30-inch mains of the older pipe-system. Three steam-engines, one of which is in reserve, are capable of sending 981,785 gallons per hour through a 3·68-mile long 30-inch cast-iron main pipe into the service-reservoirs of the Belforter Strasse Works. The work of these engines is constant.

The works of the station in Belforter Strasse have been enlarged by the addition of a circular covered reservoir of 1,566,000 gallons available water-content. In this case also the walls supporting the vaults are so arranged that a stagnation of the water between its entrance and exit is prevented. In addition to this reservoir, two 90-HP. Worthington high-duty engines, with the necessary boilers and coal-stores, have been built on the space within the walls reserved in 1875 for this extension. One of these engines with its two boilers is in reserve.

For all the engines of the Müggel-Lichtenberg Works it has been assumed that the slip of the valves of the pumps is 15 per cent., that is, that the effective delivery of the pump is only 85 per cent. of the displacement of the plungers. The engines, in the three engine-houses referred to, draw the water by very short suction-pipes from a small reservoir at the pump end of each engine-house. These small reservoirs are so connected with

the main reservoirs and with each other that the engines can be fed whichever division of the main reservoirs may be inactive.

All the stations of the Berlin Waterworks are in telegraphic (Morse code) and telephonic connection with each other and with the central office in the city. A float in the service-reservoirs of the Belforter Strasse Station, on falling or rising 2 inches, forms a metallic connection between two wires, and sends an electric current into the engineer's office and the Belforter Strasse engine-house of the Lichtenberg Works, showing thereby on a dial and registering on a strip of paper the water-level in the reservoirs. By a precisely similar arrangement the level of the water in the Lichtenberg service-reservoirs is shown and registered in the office and in the engine-house of the Lake Müggel Works.

Cost.—As compared with similar works in England the cost of these works has been high. For reasons well known, foreign firms could not compete for the supply of the pipes or the machinery. The straight pipes cost between £6 15*s.* and £8 per ton, and the covered filters at least £15,000 per acre of filtering surface.

Conclusion.

The Author has endeavoured to record in this Paper the investigations made to ascertain the principles which should guide engineers in designing works to meet such circumstances as obtain in Berlin, and the manner in which they have been applied to the works for the water-supply of that city. The investigations as to the filtration of river-water are given in some detail in order to justify the use of arrangements, the necessity of which has not hitherto been acknowledged, and of precautions in the management of filters—given in the instructions—hitherto not observed. Whatever differences of opinion may exist as to the necessity of removing bacteria as far as possible from water intended for domestic use, there can be no doubt that the fewer passing into the premises of the consumer, and the quicker that water which does reach the latter is consumed, the better. But, even where the water to be filtered contains relatively few bacteria, and the chief attention has to be directed to the removal of inorganic particles in suspension, causing turbidity, there can be little doubt that the appliances here described, and the method of management recommended, will lead to much more satisfactory results as regards the quality of the filtered water, and greater economy in its production, than it has hitherto been possible to attain.

The Paper is accompanied by eighteen drawings, from a selection of which Plate 7 and the *Figs.* in the text have been prepared.

APPENDIXES.

APPENDIX I.

MUNICIPAL WATERWORKS, BERLIN.—TABULAR STATEMENT OF THE RELATION BETWEEN THE QUANTITY OF WATER SUPPLIED TO THE CITY ON THE DAY OF MAXIMUM CONSUMPTION AND THE AVERAGE DAILY CONSUMPTION OF THE YEAR.

X				Y		
For the Population of the entire City.				For the Population of the Upper Zone.		
1	2	3	4	5	6	7
Year.	Population supplied, including that on the Upper Zone of the Pipe-System.	Ratio. Average Daily Consumption of Year.	Ratio. Supply on Day of Maximum Consumption.	Population on the Upper Zone of the Pipe-System.	Ratio. Average Daily Consumption of Year.	Ratio. Supply on Day of Maximum Consumption.
1879–1880	842,803	100	127	97,574	100	147
1880–1881	887,501	100	130	102,355	100	138
1881–1882	935,435	100	132	109,435	100	135
1882–1883	968,141	100	134	115,257	100	121
1883–1884	1,050,977	100	147	125,826	100	166
1884–1885	1,086,859	100	134	131,948	100	134
1885–1886	1,119,285	100	140	140,736	100	138
1886–1887	1,147,468	100	134	149,282	100	151
1887–1888	1,304,265	100	140	172,077	100	152
1888–1889	1,334,088	100	146	179,305	100	135
1889–1890	1,388,530	100	149	190,617	100	162
1890–1891	1,427,148	100	132	207,818	100	143
1891–1892	1,596,291	100	133	236,633	100	139
			$\frac{1,778}{13}=137$			$\frac{1,861}{13}=143$

NOTE.—The Law is illustrated by Columns 6 and 7 of Table Y, inasmuch as the service-reservoirs of station Y (Belfort Works) are supplied in each of the twenty-four hours with about one twenty-fourth part of the daily quantity required by the population of Y out of the pipe-system of the works X. But for this constant, the average of Table X would approximate closely to the average of Table Y.

APPENDIX II.

TABULAR STATEMENT, FOR THE WATERWORKS IN GERMANY WHICH SELL WATER EXCLUSIVELY BY METER, OF THE RELATION WHICH THE CONSUMPTION ON THE DAY OF MAXIMUM SUPPLY BEARS TO THE AVERAGE DAILY SUPPLY OF THE YEAR.

1	2	3	4	5	6
			Water supplied in Twenty-four Hours.		
Town.	Year.	Population supplied.	Average of the Year.	On Day of Maximum Consumption.	$\frac{\text{Col. 5} \times 100}{\text{Col. 4}}$
			Cubic Met.	Cubic Metres.	Per cent.
Basel	1890	72,500	7,931	11,059	139·4
Bayreuth	1891	25,000			
Berlin	1890–91	1,427,148	97,017	129,633	133·6
Bochum	1891–92	136,000	22,454	28,559	127·2
Brunswick	1890	100,000	6,914	10,269	148·5
Chemnitz	1890	138,665	5,731	9,875	172·3
Danzig	1890	106,707	10,111		
Danzig (Vorstadt)	1890	11,600	189		
Elberfeld	1890–91	135,000	13,306	17,879	134·3
Giessen	1890–91	21,000	360	587	163·1
Gotha	1891	30,000	2,000	2,600	130·0
M. Gladbach	1890–91	50,000	2,500	4,000	160·0
Greiz	1890	20,000	462		
Lindau	1890	5,349			
Magdeburg	1890–91	198,000	18,100	22,793	125·9
Mannheim	1890	79,000	3,960	7,570	191·1
Minden	1890–91	21,000	493	613	124·3
Münster	1890–91	49,000	2,517	3,729	148·2
Plauen	1890	47,000	2,000		
Posen	1890–91	70,000	3,238	5,758	177·8
Quedlinburg	1890–91	20,000	572	709	124·0
Remscheid	1890–91	41,000	1,084	1,593	147·0
Stade	1891	10,200	242	440	181·8
Strassburg	1890–91	95,034	6,282	10,905	173·6
Weimar	1890–91	24,500	1,338	1,793	134·0
Wiesbaden	1890–91	62,000	4,835	7,200	148·9
Worms	1890–91	26,000	2,630	3,700	140·7
			Average of 21 towns		$=\frac{3,125\cdot7}{21}=148\cdot8$

APPENDIX III.

Total Quantity of Water delivered to Berlin on the 13th August, 1892.

1	2	3	4	5
Hour.	Consumption in each Hour.	Percentage of the Total Consumption in Twenty-four Hours.	The Percentage of each Hour compared with the Average Percentage of Twenty-four Hours.	
			Greater.	Less.
Midnight.	Cubic Metres.	Per cent.	Per cent.	Per cent.
12– 1 A.M.	2,557	1·698	..	2·468
1– 2 „	2,648	1·759	..	2·407
2– 3 „	2,346	1·558	..	2·608
3– 4 „	2,475	1·644	..	2·522
4– 5 „	2,610	1·733	..	2·433
5– 6 „	3,974	2·639	..	1·527
6– 7 „	6,056	4·022	..	0·144
7– 8 „	7,483	4·969	0·803	
8– 9 „	9,023	5·992	1·826	
9–10 „	9,071	6·024	1·858	
10–11 „	8,971	5·958	1·792	
11–12 noon	9,368	6·221	2,055	
12– 1 P.M.	8,554	5·681	1·515	
1– 2 „	8,527	5·663	1·497	
2– 3 „	8,362	5·553	1·387	
3– 4 „	8,673	5·760	1·594	
4– 5 „	8,728	5·796	1·630	
5– 6 „	8,430	5·598	1·432	
6– 7 „	7,499	4·980	0·814	
7– 8 „	6,942	4·610	0·444	
8– 9 „	5,694	3·781	..	0·385
9–10 „	5,205	3·457	..	0·709
10–11 „	4,322	2·870	..	1·296
11–12 midnt.	3,063	2·034	..	2·122
	150,581	100·000	18·647	18·621

The relation of the maximum hourly consumption to the average hourly consumption is as $\dfrac{9,368}{\frac{150,581}{24}} : 1$; *i.e.*, as 1·49 : 1.

APPENDIX IV.

INSTRUCTIONS FOR THE MANAGEMENT OF THE FILTERS OF THE LAKE MÜGGEL WORKS.

1. *Starting the Filters.*

The setting in action of a sand-filter prepared ready for work begins with the filling. This consists in forcing out the air contained in the filter-material, for which only filtered-water rising slowly upwards from the floor of the filter may be used. For this purpose the emptying-cock G, *Fig. 2*, must first be closed, and then the filtered-water-cock A, and the emptying-cock B, opened. The regulating-sluice C is then opened, but only so far that at least ten hours elapse before the filtered-water running in from the neighbouring filter-basins appears upon the sand-surface. The gradual rise of the water is indicated by the float in the sluice-chamber.

Should the filling be done too quickly, especially after the filter has been long in use when the sand-layer has become compact, there is danger that the air which is being forced upwards may break through some of the less compact parts, and thus cause irregularities in the porosity of the sand, or that it may in part remain in the sand in the form of large flat bubbles which subsequently unexpectedly force for themselves a way through the sand during the working.

As soon as the filtered-water used for filling has risen to a height of 10 centimetres (4 inches) over the sand the emptying-cock B and the regulating-sluice C are closed, and the feed-cock E is slightly opened, so that the unfiltered water flows in slowly so as to avoid a disturbance of the sand-surface. As soon as the layer of water has reached the height of ½ metre (1·6 foot) above the sand-surface the feed-cock E is opened wider, so that the filter may be filled more quickly. The water-level in the filter must not rise above 12 centimetres (4·7 inches) per hour, so that the incoming water never attains such a speed as to disturb the sand-surface.

The inflow can be regulated exactly by means of the feed-cock. The filter-basin is filled in this manner up to the lip of the overflow-pipe. An overflow is prevented by the automatic valve H.

2. *Process of Filtering.*

A filter filled according to the directions contained in § 1 should not, if the working permits, be taken into use at once, but should be left standing for twenty-four hours, in order that the pores of the sand-surface may be somewhat closed by sedimentation. But even when the working does not permit of this, the filter must be brought very gradually up to its normal work. The starting and the gradual progress towards the normal work is brought about by the regulating-sluice C being slightly raised, but only so far that the water-level in the weir-chamber does not stand higher than 40 millimetres (1·57 inch) above the lower lip of the orifice *y*, *i.e.*, a level of 122·38 feet above datum; whereupon by raising the sluice at definite intervals of time, the area of the passage is so gradually enlarged that about sixty hours elapse before the water-surface in the weir-chamber reaches the normal height of 0·62 foot, or the level 122·87 feet above datum, beyond which it must not rise. With this depth of water every basin will perform its normal work of 7·87 cubic feet of water per square foot of sand-surface in twenty-four hours.

It is the duty of the filter-watchman, after opening the feed-cock E, to see that

the automatic valve H keeps the filter filled permanently up to the level of the upper lip of the overflow-pipe; and, on the other hand, by opening and closing the regulating-sluice C, to cause the water-level in the weir-chamber to remain at the height of 0·62 foot above the lower lip of the orifice *y*. The various levels of the water in the sluice-chamber, the weir-chamber, and in the filter itself are marked in each case by a float actuating a pointer moving over a scale fixed in the upper floor of the regulating-house.

It is most important that a sudden fluctuation of pressure be avoided. Every sudden change of the pressure on the layer of mud which is gradually deposited on the sand reduces at once the clearness of the filtered water. The same effect is produced by each change in the rate of discharge. In order therefore to avoid such evils and to ensure that the discharge of the filter is always uniform, the watchman must take particular care that the water-height over the submerged orifice in the weir-chamber, through which the filtered-water flows, does not alter, but is maintained as nearly as possible at the height of 0·62 foot above the lower lip of the orifice, that is, remains in the prescribed normal ordinate of 122·87 feet above datum. After the normal working speed has been attained, the resistance to the passage of the water through the sand-layer increases regularly and gradually with the increase of the thickness of the deposit on the sand. The regulating-sluice C must, therefore, be as gradually raised, thereby increasing the head of water on the sand. As a rule, and until further instructions, this sluice must never be raised so far that the difference of levels between the water-surface in the filter and the water-surface in the sluice-chamber amounts to more than 1·64 foot. If, when this difference has been reached, the water-height above the orifice cannot be maintained, the filter must be put out of use and cleaned. Hygienic considerations may make it necessary, under certain conditions, not to extend the time of working so long.

When a filter has been for some weeks in action organic matter collects on the sand-surface, which matter, deprived of its free movement in the water, may die, and in summer putrefy. The passage of water through a putrefying mass may become dangerous. It is a sign of advanced putrification when spongy masses float on the surface of the water in the filter. These rise from the bottom and are parts of the deposit of mud and organic matter which from being charged with gas have become buoyant. As soon as they show themselves in considerable quantities, which may occur in very hot weather, it is time to stop the working of the filter and clean it, even when it works sufficiently well as regards the water-delivery.

3. *Emptying and Cleaning Filters.*

When a filter is to be emptied for cleaning purposes the feed-cock E must first be closed. Then the filtered-water-cock A, and the valves F F, attached at the level of the surface of the sand to the overflow-pipe, must be opened and the filter emptied to the level of the sand-surface. When this is done the emptying-cocks B and G must be opened so that the water remaining in the filter-material may flow away and the filter be emptied, either to the bottom of the gravel-layer or to the floor, the object being so to free the sand from water that the labourers can move about and work on it without sinking into it or injuring its compact surface. As the water leaves the sand and the coarser underlayers, the air enters the voids thus created, and its entrance is assisted by the vertical air-channels at the enclosing walls, which reach down to the floor. When the filtration takes the course prescribed in § 2, the deposit is prevented from penetrating deep into the sand-layer and remains almost in entirety on its

surface. It is sufficient therefore to remove carefully with shovels a sheet of sand at most 0·4 inch thick. The paring-off of the thin sand-layer requires experienced workmen, and especial care must be taken not to remove too much sand. The cost of working depends considerably on this.

The sand pared off in each vaulted division of 205·6 square feet is thrown together in a heap in the middle of it, and, after the whole sand-surface of the filter has been pared off, is removed in barrows to the store for dirty sand. After the heaps of deposit have been cleared away, the upper surface of the sand is smoothed to a flat surface with implements which may be called wooden rakes without teeth, care being taken to disturb as little as possible the compact surface. The sand-surface is laid with a fall of 2·4 inches from the back wall to the valves F F, in order to facilitate the discharge of the water; care must be taken to maintain this inclination.

After a filter has been cleaned it should, if possible, be exposed for some time to the action of the atmosphere. If the filter be not required at once it should remain empty, and, except in winter, the glass coverings of the openings of the vaults should be raised to assist the ventilation. In winter, to avoid the formation of ice, the above-mentioned glass coverings in the centre of each vault must be covered with boards, by which means the radiation of heat is prevented.

Of the eleven filters of each of the four divisions, eight are sufficient, at the normal delivery of 7·87 cubic feet per square foot in twenty-four hours, to filter the quantity of water which the pumps of each subdivision are able to lift to Lichtenberg. Under normal circumstances, therefore, there are in each subdivision eight filters working and three kept in reserve. In order to prevent the unnecessary transport of barrow-run planks and plant during the cleaning of the filters, this operation should be taken in succession according to a prearranged plan, which can be done without difficulty.

4. *Renewal of Sand.*

The sand removed from the filter is not replaced until the cleaning process has been repeated many times, because, in the first place, it is difficult to lay on a very thin layer of sand; and, secondly, the working of the filter would thereby be too frequently interrupted. Although the filtration would not suffer if the 600 millimetres (2 feet) thick layer of sand were reduced to half its original thickness, yet the chemical reaction of the sand would gradually decrease. For this reason the replacing of the sand removed during the process of cleaning must be taken in hand as soon as the thickness of the sand-layer has been reduced by 200 millimetres (8 inches). For the barrowing-in of the sand only a small gang of workmen should be employed; the smaller the number of workmen, the shorter are the pauses which each man makes in going and coming.

At certain intervals of time, if necessary, before bringing in fresh sand, the side-walls and piers of the filter-basins must be cleaned and freed from the organic deposit which may have settled on them. The water which is to be let off may be used for this purpose. This washing can only be done by means of a small boat or raft. The deposits on the walls serve as breeding-places for micro-organisms which cannot improve the quality of the water; their removal is therefore desirable.

5. *Washing of Sand.*

The sand removed from the filters during the process of cleaning is washed and used again. The washing must be done so thoroughly that a sample of the cleaned sand stirred in a glass of clear water does not show turbidity.

In order to attain this the following points must be attended to:—

(a) The duration of the washing process must be prolonged according to the coarseness of the sand and the mass of deposited mud by decreasing the number of rotations per minute of the drum, the quantity of the washing-water remaining unchanged.

(b) At the same time the circular weir at the larger diameter of the drum by which the dirty water escapes must be raised in order to increase the quantity of water in the drum. The inorganic impurities of the sand which produce mud in the water, can be removed easily by washing. On the other hand the organic matter, the algæ, cause a serious difficulty. These form matter much more difficult to remove if the damp sand from the filters be not washed at once, but left heaped up in a temperature favourable to the growth of plants of such low order. The dirty sand must therefore be washed, if possible, as soon as it is barrowed out of the filters. The dirt and mud washed out of the sand fall into the catch-basin, where they sink to the bottom. The waste water flows over the weir clarified and free from solid matter. The fine sand lifted out of the drum with the filter-sand after escaping from the delivery-trough is flushed into the sand-catch chamber and is deposited there. The water, however, flows away over a long weir clear and free from sand. Deposits in the waste-culvert are thus avoided. It is the business of the filter-foreman to see that these catch-basins are cleaned out as soon as necessary.

(*Paper No. 2819.*)

"The Rajkot Waterworks, Bombay."

By Robert Bell Booth, M. Inst. C.E.

This work was carried out in commemoration of the Jubilee of Queen Victoria. In June, 1887, the States of Kathiawar subscribed 1,60,000 rupees for the purpose of commemorating the event by some public work at the political and military head-quarters of the Province; but it was not until November, 1889, that the waterworks were commenced. This was owing partly to diversity of opinion as to the form the memorial should take, and partly as to what was most needed for the welfare of the station. The delay decided the question; for the water-supply from wells, which had for years been variable and uncertain, became so seriously insufficient in 1887–8 that all other proposals were abandoned in favour of a water-supply by any available means, and the problem was placed in the hands of the Author for solution.

After various trials and surveys it was determined to construct a masonry dam across the Randarda Valley at its narrowest point, about 2 miles from the station, the deepest part of the valley here being on a level with the highest part of the civil station, and thereby to form a lake of sufficient extent and elevation to provide the necessary quantity and head for gravitation. The area of the gathering ground of the Randarda Valley above the proposed dam, 6½ square miles, would not in some localities have been large enough to ensure impounding a sufficient volume of water in unfavourable years; but as it was mostly of hard, undulating and hilly land, with much moorum and rock at the surface, and but scanty vegetation, it was hoped that the discharge would be considerably more than in ordinary districts, and sufficient, even in dry years, to fill the proposed basin. This surmise has proved to be nearly correct. The survey was carried out by the Author, and the plans and estimates were submitted to Government for approval at the latter end of 1888. In the following February Mr. S. B. Doig, M. Inst. C.E., Executive Engineer, Ahmedabad, proceeded to Rajkot

and reported favourably; and after the usual preliminaries, the works as designed were approved by the Chief Engineer and sanctioned by Government, operations being commenced in November, 1889.

There are three dams; the main dam is 1,600 feet in length, the second 400 feet, and the third or weir dam 350 feet. They are built on the trapezoidal form, the base being seven-tenths of the height. The batter at the back is $5\frac{1}{2}$ inches, and at the face $\frac{1}{2}$ inch in 1 foot. The structures are of uncoursed rubble masonry faced with hammer-dressed courses, between 6 inches and 1 foot in height. The stone for the face-courses of blue trap was brought by tramway from quarries $2\frac{1}{2}$ miles distant; that for the rubble hearting was principally basalt from the hills adjacent to the work.

The lime was made from a hard description of the ordinary sand limestone of the locality, abundance of which was found about the neighbouring hills, and was burnt in flare kilns on the spot. This lime possesses certain hydraulic properties, which cause mortar made with it to harden rapidly after a few days' settlement if it is kept wetted. It is well adapted for dam-building. The flare kilns are very suitable for burning this limestone. A circular hole 8 feet by 12 feet is made in the ground with a passage sloping to the bottom at one side. Over this orifice the limestone in large rough lumps is built up in the form of a cone or dome, and backed with smaller lumps in proportion to the thickness of the wall, which is usually between 1 and 2 feet. Outside this a lining of sun-dried bricks is laid, and the kiln is ready. The burning was done with brushwood, cotton stocks, tree prunings and similar materials collected beforehand in large quantities, and a constant and steady flare furnace was kept up from below, which in the course of twelve hours completed the burning. The lime, when sufficiently cooled, was removed from the dome, spread out, and slacked; after which it was carefully screened of all unburnt particles and carried to the mortar-mills. The sand used was black disintegrated trap, procured from the River Lalpuri, 1 mile distant. The mortar for rubble work was composed of 1 part of lime to 2 parts of sand, washed but unscreened; and for facework, 1 part of lime to $1\frac{1}{2}$ of sand screened.

The masonry was let at 11 rupees per 100 cubic feet, inclusive of all charges. The face-courses were roughly dressed from 6 inches to 9 inches inwards on bed-joints, and from 3 inches to 6 inches at the sides, and a little Portland cement was run round the outer part of each face-joint 1 inch to 2 inches inwards. The face stones

tailed inwards in the rough for 1½ to 3 times their height, and every 6 feet a header of greater length was introduced. The large stones in the hearting, which were generally greater in bulk than those of the face-courses, were carefully laid, and the spaces between them packed with smaller stones and chips with mortar, the larger stones being so placed that they dovetailed vertically and horizontally with their neighbours. It was at first intended to construct the entire dam of uncoursed rubble, though for the sake of appearance the work was not carried out in that manner.

The foundations of the dams, as is not uncommon in trap formations, gave a great deal of trouble and led to much unanticipated expense. Where, from borings originally taken, a sound rock bottom was expected at between 6 and 10 feet, it was found necessary to excavate and blast out decomposed and hard fractured rock to a depth of between 20 and 25 feet. The sound impervious rock, which lay exposed on the river-bed, dipped at some distance from the river bank, and at no place until the hills were worked into did it rise much above the level of the river-bed. A great part of the overlying rock was sound and exceedingly hard and difficult to work. Full of veins and fissures in parts, it could not be removed without much blasting. In some places, after a thickness of 6 to 10 feet of it, apparently without a flaw, had been passed through, a vein of moorum would be exposed, with a spring of water passing through, and this of course led to the necessity for further excavation until the sound rock was reached.

On entering the hill and saddle nearly 100 feet, the deep excavation was stopped, when the overlying rock proved more free of fissures, and the space between the dam and the side of the excavation was rammed in with white clay to the ground surface. The main dam is built to a height of 37 feet above the river-bed, with the exception of a small portion where the well and sluice are placed at a height of 41 feet. The central dam is 37 feet and the weir 35½ feet high. The former will also serve as a weir whenever the flow of surplus flood-water exceeds 6 inches in depth over the weir dam. It will, however, be only during exceptional rainfall that this can happen, with so large a basin to fill. The fall of the river immediately above the dam is 14 feet in a mile. The superficial area of the lake when full will be 2,000,000 square yards, and the capacity from 8 feet above the bed of the river, being the level of lowest inlet pipe, 5,350,000 cubic yards.

Some notes and instances of the discharge of water from the gathering ground are given in the Appendix.

For the conveyance of the water to Rajkot, a well, 10 feet in

diameter, was constructed on the upper side of the main dam, at the deepest point. In this were placed three inlet-pipes 10 inches in diameter at 8 feet, 17 feet, and 25 feet respectively from the bottom. At the back of the well a recess 4 feet by 2½ feet was built, from which at 2 feet above the floor of the well the outlet-pipe, 10 inches in diameter, emerges. The recess is divided from the well by a series of removable iron frames fitted with fine copper wire-cloth, through which the water is strained. The inlet-pipes are fitted with galvanized iron perforated screens on the lake side. The inlet- and outlet-pipes are provided with valves on the inside, worked by rods passing through an iron floor on the top of the well. At the bottom of the well a scour-pipe and valve 1 inch in diameter is placed for clearing out the deposit. The well and recess are lined with a coating of Portland cement ½ inch thick. No leakage has occurred through any part of the dams under a pressure of 35 feet head of water. A small tower room is constructed over the well. The main dam is protected on both sides with open work parapets having a paved floor between, and forms a fine promenade. A 9-inch main conveys the water into the station 2½ miles distant. From thence two mains, 8 inches and 5 inches in diameter, carry it into the more thickly inhabited parts; and thence in turn smaller branch mains, some 5 miles in length, conduct the water along the principal roads and streets. Stand-posts for drinking-supplies, with troughs for cattle fitted with automatic ball-valves, occur at convenient localities; and two large service-tanks or drinking-fountains, where the water is filtered before passing into the taps, are erected in the most populous parts of the bazaars. One of these reservoirs, presented by H.H. the late Nawab Saheb of Junagarh, is 25 feet high, and is built in two compartments. The walls at the base are 9 feet, and at the top 4 feet thick. The rear compartment, the capacity of which is 616 cubic feet, receives the water at a height of 8 feet from the floor from a 4-inch pipe. This compartment, to a height of 7 feet from the floor, is filled with sand and gravel through which the water passes before entering the main compartment by perforated channels through the base of the divisional wall. The inlet-pipe is fitted with a sliding valve connected with a vertical rod upon which a metallic cylinder slides. On the water reaching a certain height, the valve is closed by the cylinder coming into contact with a disk fixed on the rod. As an additional precaution, safety-pipes are placed at the top of each compartment.

The main reservoir holds 28,000 gallons of filtered water, and is provided with twenty-seven Kelvin screw-down taps.

Three 1½-inch connections for fire-hose are also provided. Niches for supporting water-vessels below the taps are formed in the masonry, and waste water is led into receptacles, from whence it is taken for watering the surrounding gardens. By this means all unsightliness is avoided; and the reservoir, with its surrounding grounds laid out in walks and grass plots, is an ornament to the station. The other reservoir, constructed in memory of the late Bawa Mia Fouzdar, for the exclusive use of the lower castes, is on a similar principle but considerably smaller. Fire-hydrants, which are used also for filling watering-carts, are erected at intervals along the populous parts of the bazaar.

COST OF THE WORK.

	Cubic Feet.	Rupees.
Earth excavation	215,000	400
Moorum, &c.	195,000	2,600
Rocks, &c.	182,000	9,000
Masonry dams, including pavements, towers, parapets, &c.	850,000	96,500
Pipes (490 tons) delivered at Rajkot		45,500
Sluice-gate, &c.		5,500
Laying pipes		7,500
Stand-posts		1,000
Reservoir and fountains in station		17,000
Establishment and sundries		18,000
Total		2,03,000

The works were commenced in November, 1889, and in June, 1891, water was led into the civil station. During the following year the dam and pipe service were completed, and the works were formally opened on the 2nd of August, 1892. The supply has exceeded anticipation. The water is excellent and abundant; there is no leakage, and the lake will from ordinary rainfalls contain a two years' supply with a considerable surplus. Since the water was laid on for the station and cantonments, the city also has been urgently calling for a water-supply; and proposals are now before Government for the formation of a much larger lake, 3 miles from the city, to be used for irrigation and city supply conjointly.

[APPENDIX.

APPENDIX.

NOTES AND INSTANCES OF THE IMMEDIATE DISCHARGE OF WATER FROM THE GATHERING GROUND, RANDARDA VALLEY.

(a) Before the rains of 1891 the height of the weir dam had been increased to 31½ feet. The level of the lake rose from 13 feet to that of the weir dam in a week, with a total rainfall of 12 inches; hence the following details for immediate discharge can be deduced:—

	Cubic Feet.
12 inches' rainfall per square mile	27,750,000
12 „ „ for 6½ square miles	180,375,000

Capacity of lake between 13½ and 31½ feet contours = 104,390,000 cubic feet, so that the immediate discharge was more than one-half the rainfall.

The fall of water in the lake between the 15th of September, 1891, and the 31st of May, 1892, was 8 feet 10 inches, equal to an average of about 10½ inches per month. The reduction of water from evaporation and other natural causes during the cold months, November to March, was 0·2 inch per day, and from draw-off 180,000 gallons, or 0·05 inch per day. During the hot months the former was increased from 0·3 inch to 0·4 inch, and the latter to 0·1 inch.

The above-mentioned discharge of one-half the rainfall could only occur at the commencement of the rains, when the ground is bare of vegetation and hard, and when the rain falls quickly and heavily. In this case 5·43 inches fell in one night, and was followed by another fall of nearly 3 inches.

(b) The following details relate to the year 1892:—June 6th. The rainfall, 4 to 6 P.M., at the upper end of the lake was 2 inches, and at the dam 1·3 inch. The level of the lake rose from 22½ to 25 feet.

Area of lake at 23¾ contour, 5,109,300 square feet; contents at 2½ feet, 12,783,250 cubic feet. Assuming 2 inches' rainfall on 6½ square miles the volume was 30,203,200 cubic feet; so that considerably more than one-third of the fall immediately ran off; or, taking the average rainfall at 1⅔ inch over the whole area, the immediate discharge would have been about one-half the fall. This corresponds with the previous year's record for early and heavy falls.

(c) June 18th, height of lake 26 feet 4 inches; July 18th, 29 feet. Mean rainfall over the catchment area 5·6 inches; rise of lake 2 feet 8 inches; area of lake at 27½ feet (mean), 7,736,000 square feet; volume of water represented by a rise of 2 feet 8 inches, 20,629,848 cubic feet; total volume of water which fell on gathering-ground, 84,500,000 cubic feet. Immediate discharge under one-fourth.

(d) Between July 19th and August 19th the lake-level remained practically at 29 feet, falling an inch or two and again rising to the same level, while the total rainfall during the month was 5·7 inches.

This is due to the small quantities which fell at a time, and to the rain being generally light and in short showers. The greatest fall during the month did not exceed 1·5 inch in twenty-four hours; and at this date the grass and crops had grown up on the catchment area, and held the rain-water from flowing off before most of it had sunk into the ground or evaporated. In one instance an average rainfall of 0·84 inch produced a rise of lake of 2 inches only, being

about one-tenth of the rainfall; but from the observations of the entire month, only one-twenty-eighth of the rainfall was impounded; or, assuming the evaporation to be $\frac{1}{4}$ inch per day, the water impounded from immediate discharge would have been about one-fourteenth of the fall.

Between the 19th of August and the 20th of September 3·70 inches of rain fell; but it made no impression on the lake beyond the rise or fall of $\frac{1}{2}$ inch. On the 21st of September rain fell heavily in the afternoon for two hours, 2·19 inches at the dam, and 1·24 inch at the upper end, and the level rose $5\frac{1}{2}$ inches, bringing the total height to 29 feet 4 inches. On the night of the 22nd it rained 2·17 inches over the catchment area, and the level rose 13 inches, or in all to 30 feet 5 inches; and on the 24th from another fall of 0·75 inch over the catchment-area the lake-level rose to 30 feet 8 inches.

Taking the rise of the lake, between the 21st and the 24th inclusive, to be 1 foot 10 inches, and the average rainfall over the gathering-ground to be 4·68 inches, the immediate discharge was slightly over one-fourth of the fall, due to the heaviness of the rain.

The last rain of the season fell on the 19th of October to the amount of 2·37 inches, from which the water rose 9 inches, bringing the full-level on that date to 31 feet 2 inches, and making the discharge about one-tenth of the rainfall.

For the five months ending March 31st, 1893, the reduction of the lake-level was 7 inches a month, from all causes, being something less than the usual loss from evaporation alone; whereas, in addition to evaporation, upwards of 250,000 gallons were drawn off daily for service.

It is evident that the light rainfall of the previous monsoon did its work in feeding the lake, perhaps more effectively than if by sudden and fast falls it had run off in larger quantities and raised the level of the basin higher than the record. It is important to know that although the effect of light rainfall may not be so immediately satisfactory, it is valuable in localities of this kind from the good service subsequently rendered in feeding wells and reservoirs. In the case of quick falls, instead of the lake-water returning to saturate the adjacent ground, the reverse is the case.

During the year 1893 one instance of an immediate discharge will be sufficient. On June 20th the average fall over the catchment area was $5\frac{5}{8}$ inches, about 80,000,000 cubic feet; while the water impounded during the twenty-four hours was 22,590,000 cubic feet, making the discharge between one-third and one-fourth the fall; but the lake rose 2 inches during the following twelve hours from streams draining off the ground and light rain; so that the total discharge was nearly if not quite one-third of the rainfall.

In making calculations for discharge in Kathiawar districts, one-fourth of the rainfall seems to be well on the safe side.

(*Paper No. 2782.*)

(*Abstract.*)

"Note of an Experiment on the Friction in a Water-Main."

By CHARLES ARTHUR FRIEND, M. Inst. C.E.

THE observations described in this Paper were recently made to determine the loss of head in the cast-iron water-main supplying the city of Seville from a reservoir 7½ miles distant, when discharging at its maximum daily rate. This main was laid in 1884, and, so far as can be ascertained, is free from corrosion or deposit.

The pressure was observed by a gauge in the sluice-house in Seville, and the loss of head deduced in each case is the difference between this pressure or head and the static-head, or difference of levels between the pipe at the sluice-house and the level of the water in the distant reservoir. The instrument used to measure the pressure in the sluice-house was a Bourdon gauge, which had been tested for the purpose of the experiment and found to be indicating correctly. The length of the main between the reservoir and the sluice-house was 42,050 feet, and its diameter was 21 inches. The quantity of water flowing in the main was calculated from hourly readings of the level of the water in the reservoir in conjunction with those of the revolutions of the pumping-engine, the amount of water pumped into the reservoir per stroke of the pump being known.

In all, twelve results are given in the Paper, calculated from the average rate of flow, and the average pressure observed during each one of twelve hours. It was found that the actual rate of delivery of the main more nearly coincided with the value indicated by accepted formulas, as the period of maximum flow was approached; at which time the variation of pressure indicated by the gauge was a minimum. Of these results, however, one only, that for the hour 10–11 A.M., during which the pressure was steady, is regarded as reliable. The following statement of this result shows, in addition to the observed loss of head, that

deduced from Darcy's formula for clean pipes, which, transposed, gives

$$h = \frac{l\,Q^2}{1850\,d^5},$$ [1]

and from Unwin's formula for new pipes, which gives

$$h = \frac{l\,Q^2}{1887\,d^5},$$ [2]

where h, l, and d are the loss of head, length of the pipe, and diameter of the pipe respectively in feet, and Q is the rate of flow in cubic feet per second.

Hour.	Rate of Flow.	Loss of Head.		
		Observed.	Calculated from Darcy's Formula.	Calculated from Unwin's Formula.
	Cubic Feet per Second.	Feet.	Feet.	Feet.
10–11 A.M.	7·098	63·57	69·03	68·29

[1] "Mouvement de l'Eau dans les Tuyaux," H. Darcy, Paris, 1857, p. 110, and "The Principles of Waterworks Engineering," Tudsbery Turner and Brightmore, 1893, p. 70.

[2] Art. "Hydromechanics," *Encyclopædia Britannica*, 1881, vol. xii., p. 288.

(*Paper No. 2713.*)

"On the Rainfall discharged from Catchment-Areas."

By William Kitson Stent, M. Inst. C.E.

The information presented in this Paper was obtained mainly with reference to the fixing of water-ways on the Villupuram-Guntakal Railway—a branch of the South Indian Railway on which the Author was employed.

In India, records of the rainfall have now been generally maintained for upwards of twenty years, and the approximate average annual rainfall of most districts is available for the determination of the discharge of rain from any catchment-area. The rainfall of India, however, presents as wide a range as that of any country in the world—from Cherra Punji in Assam, with an average fall of 490 inches, to the province of Sind where only 3 to 5 inches of rain fall annually. The Author was some years ago led to investigate how far there is a fixed relation between the maximum annual and the mean annual rainfall, and he found the relation fairly constant with widely different rainfalls. This matter has since been dealt with so thoroughly by Mr. A. R. Binnie,[1] that the fact is no longer open to question. The result, obtained by the Author from the records of fifty stations taken from the Indian Meteorological reports, is higher than that given in Mr. Binnie's Paper or quoted in the discussion thereon. In 14 per cent. of the cases, the maximum is double the mean rainfall; while in 18 per cent. the maximum fall is only 50 per cent. in excess of the mean annual fall. It appears, also, that the maximum fall in any one month bears a fairly constant ratio to the mean annual fall. In order to make the relation subsisting between maximum and mean rainfall of any value for discharge formulas, it is necessary to show that it obtains in regard to maximum daily falls, and then, if possible, to maximum falls within shorter periods. All that the Author proposes to attempt now is to show that in the special case he investigated this relation exists as regards daily falls.

[1] Minutes of Proceedings Inst. C.E., vol. cix. pp. 89 *et seq.*

The rainfall on the district under consideration may be divided into three sections. The southern portion, extending as far north as Vayalpad, belongs to the area included in the Carnatic rainfall; the northern portion belongs to the area of limited rainfall of which Bellary is the centre, extending from Guntakul south to Kadiri and Hindupur; the portion of the railway between Vayalpad and Kadiri holds an intermediate position between these two. The Carnatic receives some rain from the south-west monsoon (May to September), though the greater portion falls on the Western Ghâts. It depends on the north-east monsoon (October to December) for its main supply; and it is at this period that maximum rainfall and discharge of the rivers usually occur, as the south-west monsoon has kept the country moist and the rivers discharge freely on receiving the north-east rains. The northern portion also receives most of its rain from the north-east monsoon, the rain from the south-west being light and variable. In each section during the October-December rains, excessive rainfall and corresponding floods may be expected. With the assistance of the Meteorological Reporter to the Government of Madras, it has been possible to obtain some records of daily falls of rain during a period of twenty years, over this area. The rainfall stations on the route traversed are numerous, and information is afforded in Appendix, Table I, for the Villupuram-Guntakal Railway, as to the maximum annual rainfall compared with mean annual rainfall, the minimum annual rainfall and its percentage of the mean, the maximum daily rainfall and its percentage of the mean, and the month in which this took place.

The frequency of heavy daily rainfall for twelve stations during the periods given is shown in Table II of the Appendix. It will be seen from Table I that the average maximum monthly rainfall was 64 per cent. of the mean annual rainfall and ranged from 54 per cent. to 95 per cent., and that the maximum fall in one day averaged 24 per cent. of the mean annual fall with a range of 18 to 35 per cent. These falls all took place within the October-December period. Heavy falls occurred in some places at the commencement of the south-west monsoon; but these have not been included, as at that season the country is very dry and considerable absorption takes place. From an examination of the data contained in the Tables, it appears that the maximum daily rainfall may fairly be taken, for the purpose of computing the maximum discharge, at 30 per cent. of the mean annual rainfall. The Author is not prepared at present to state that this ratio is applicable generally, but he believes that it will

be found fairly correct for annual rainfalls of 15 inches to 80 inches all over India. The records of heavy showers are very incomplete; the unit adopted by the Meteorological Department is twenty-four hours, for smaller periods little information is available. Falls of 6 inches per hour are recorded over limited areas, and many of less amount. The Author suggests that it would probably be sufficient to allow between 8 per cent. and 12 per cent. of the mean annual rainfall as the fall in one hour, the smaller value applying to the larger area.

The Author considers that Mr. James Craig's formula[1] is well suited for adaptation to a coefficient varying with the mean annual rainfall. The formula may be expressed—

$$D = 440 \times P \times \Sigma \cdot B \times \log_e \frac{8\,L^2}{B} \times V,$$

where D = discharge in cubic feet per second.
P = a coefficient depending on the rainfall (according to Mr. Craig, 0·18 for all India).
V = velocity in feet per second.
B and L as indicated in Mr. Craig's Paper.

The formula without the factor V gives the section of the river in square feet at the normal velocity; and in many cases this is all that is required, the designer of a bridge having only to consider what contraction can be permitted, or the maximum velocity permissible for the approaches. The Author proposes to deal with the value of P.

From the examples given by Mr. Craig it appears that—

	P.	Fraction of R.
1. Damudar River at Ramghur	0·16	0·0032
2. " " Gurgee Nuddeo	0·14	0·0028
3. " " Burrakur	0·18	0·0034
4. Kulliani River	0·18	0·0045
5. Goomtee River at Lucknow	0·14	0·0039
6. Movena " Akola	0·18	0·0041
7. Sohan " Peshawar Road	0·14	0·0047
8. Irrawady River	0·18	0·0034

The mean annual rainfall, in inches, R, of these localities is as follows:—

1. 50; 2. 50; 3. 53; 4. 40; 5. 36; 6. 44[2]; 7. 30; 8. 53[3].

The second column in the Table gives the fraction of the mean

[1] Minutes of Proceedings Inst. C.E., vol. lxxx. p. 211.
[2] This is a mean between Akola and Mahla whence the river comes.
[3] At Prome.

annual rainfall equivalent to the coefficient adopted by Mr. Craig, and ranges from 0·003 to 0·005 of the mean annual rainfall, R.

In Mr. Craig's formula, this fraction of R may be substituted for P, and the expression may thus be made to vary with the intensity of the rainfall. The formula will then read—

$$D = 440 \times 0\cdot003 \text{ to } 0\cdot005\ R \times \Sigma B \times \log \frac{8\,L^2}{B} \times V$$

$$= 1\cdot32 \text{ to } 2\cdot20\ R \times \Sigma B \times \log \frac{8\,L^2}{B} \times V,$$

or $$1\cdot5\ R \times \Sigma B \log \frac{8\,L^2}{B} \times V, \text{ for large areas,}$$

$$2\ R \times \Sigma B \log \frac{8\,L^2}{B} \times V, \text{ for moderate areas,}$$

and $$2\cdot5\ R \times \Sigma B \log \frac{8\,L^2}{B} \times V, \text{ for small areas.}$$

Comparing this with Mr. Craig's figure of 80 for all India for 50 inches,[1] the values of the first term would be 75, 100 and 125, for 30 inches 45, 60 and 75. The Author believes that a coefficient varying with the value of R has been shown to be reasonable and more likely to be correct. The exact coefficient to be used should be determined by each observer.

In conclusion the Author wishes to express his thanks to Mr. David Logan, M. Inst. C.E., the chief engineer of the South Indian Railway, for the facilities afforded him to make the inquiries the results of which are contained in the Paper.

[1] Minutes of Proceedings Inst. C.E., vol. lxxx. p. 212.

[APPENDIX.

APPENDIX.

TABLE I.—RAINFALL ON THE VILLUPURAM-GUNTAKUL RAILWAY.

Station.	Mean Annual Rainfall.	Maximum Annual Rainfall.	Percentage of Mean.	Minimum Annual Rainfall.	Percentage of Mean.	Maximum Monthly Rainfall.	Percentage of Mean.	Maximum Daily Rainfall.	Percentage of Mean.	Month of Maximum Rainfall.
	Ins.	Ins.		Ins.		Ins.		Inches.		
Cuddalore . .	46	102	220	20	43	44	95	15·40	33	Dec.
Villupuram . .	36	..	..	..	..	..	..	9·15	35	"
Tindivanum .	43	79	180	21	49	26	60	12·00	28	"
Tirukovilur .	34	..	..	..	..	..	..	9·80	28	"
Tiruvannamalai	33	..	..	..	..	..	..	9·00	27	"
Polur . . .	35	..	..	..	..	..	..	9·20	26	"
Arcot . . .	36	55	150	12	33	20	55			
Vellore . . .	37	58	160	13	35	25	67	8·60	23	Nov.
Palmaner . .	31	53	170	12	39	17	55			
Chittoor . . .	35	52	150	11	31	19	54	6·00	18	"
Chandragiri .	34	48	150	9	26	21	61			
Tirupati . .	..	..	..	..	..	..	..	10·00		Oct
Piler . . .	28	..	..	..	..	..	..	5·20	19	Nov
Vayalpad . .	25	..	..	..	..	..	..	5·00	20	Sept.
Madnapalle .	29	52	180	17	59	17	58			
Kadiri . . .	25	..	..	..	..	..	..	4·30	18	Oct.
Dharmavaram .	22	46	210	6	27	12	54	4·40	20	"
Anantapur . .	20	..	..	..	..	..	..	4·50	22	"
Gooty . . .	22	45	200	9	41	16	72			
Bellary . . .	18	35	190	8	42	13	72			
Means .	..	..	180	..	39	..	64	..	24	

The records of Tirupati and Piler are for eleven and thirteen years respectively. Those of the other stations are for twenty years.

TABLE II.—RECURRENCE OF HEAVY DAILY RAINFALL.

Station.	Years of Rainfall Recorded.	Number of Times the Daily Rainfall Exceeded Inches.					Period in Years of the Recurrence of a Day's Rainfall Amounting to Inches.				
		10	8	6	4	3	10	8	6	4	3
Villupuram . . .	20	..	1	3	11	17	..	20	7	2	1
Tirukovilur . . .	20	..	1	2	7	15	..	20	10	3	1
Tiruvannamalai . .	20	1	2	3	10	20	20	10	7	2	1
Polur	20	..	1	2	10	23	..	20	10	2	1
Vellore	20	..	2	6	16	31	..	10	3	1	1
Chittoor	20	..	1	2	11	24	..	20	10	2	1
Tirupati	11	1	..	3	6	14	11	..	4	2	1
Piler	13	..	..	..	8	14	..	..	..	2	1
Vayalpad	20	..	..	..	10	15	..	..	..	2	1
Kadiri.	20	..	..	..	4	12	..	..	..	5	2
Dharmavaram . .	20	..	..	..	2	5	..	..	..	10	4
Anantapur . . .	20	..	..	..	2	6	..	..	..	10	3

NOTE.—The first nine stations relate to the Carnatic rainfall area.

TABLE III.—STATEMENT OF SIMULTANEOUS DAILY RAINFALL AT SEVERAL STATIONS.

Station.	Date.									
	1870. 1st October.	1870. 19th and 20th October.	1873. 13th and 14th October.	1880. 21st and 22nd November.	1883. 16th October.	1884. 27th September.	1884. 6th and 7th November.	1884. 18th December.	1885. 17th November.	1886. 9th and 10th November.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Villupuram	5·45	3·30	1·60	4·00	..	..	8·20	9·15	3·00	0·40
Tirukovilur	5·00	3·10	0·75	0·50	..	..	6·45	9·80	2·15	0·45
Tiruvannamalai	2·30	3·00	1·50	5·80	3·00	..	5·40	9·00	2·50	0·80
Gingee	No record	No record	No record	4·60	..	..	..	8·25	No record	0·50
Killakurchee	nil	2·04	0·50	2·80	..	..	..	No record	2·90	No record
Panrute	No record	No record	No record	No record	No record	No record	No record	8·00	No record	0·40
Tindivanum	2·50	5·60	1·35	5·00	..	..		12·00	3·30	0·55
Polur	..	2·60	2·70	5·05	1·80	1·55	3·01	9·20	3·00	0·30
Vellore	..	3·35	2·05	7·10	2·57	1·65	1·58	7·35	4·25	1·45
Chittoor	..	4·63	1·95	4·76	3·26	2·10	1·20	2·90	2·60	1·15
Chandragiri	..	4·25	1·25	4·65	..	..	..	1·55	6·00	5·10
Tirupati	No record	No record	No record	No record	No record	3·70	2·50	1·30	5·00	7·35
Arcot	..	2·50	2·40	4·50	..	..	..	6·45	4·40	0·75
Arni	No record	No record	No record	4·40	..	..	..	6·20	3·60	0·25
Gudyatum	0·50	4·20	nil	8·65	..	..	..	5·10	2·56	1·82
Palmaner	..	1·50	1·50	5·80	..	..	..	2·10	1·80	2·25
Punganur	No record	No record	No record	6·25	..	..	..	1·70	1·60	2·30
Wandiwash	..	6·00	1·30	4·55	..	..	..	7·75	5·25	0·49
Piler	..	0·85	3·10	No record	..	2·25	..	1·35	3·00	4·70
Vayalpad	..	3·00	2·20	4·00	2·70	2·80	..	1·00	2·35	4·40
Madnapalle	0·23	4·00	1·00	3·60	..	..	..	1·10	1·45	4·70
Pulivendla	..	2·00	1·30	2·00	..	..	..	0·30	nil	2·00
Rayachoti	..	4·00	0·20	1·35	..	..	..	1·20	2·20	2·65
Kadiri	..	2·00	1·35	2·00	2·50	1·90	..	0·60	0·40	3·80
Dharmavaram	2·80	0·90	0·60	0·70	2·40	1·10	..	0·15	nil	1·70
Anantapur	2·00	nil	3·60	0·40	2·15	..	..	nil	nil	1·75
Gooty	0·90	0·05	0·60	0·10	..	..	..	nil	nil	0·73
Hindupur	3·60	1·00	0·40	nil	..	..	..	nil	0·05	3·00
Penaconda	2·40	1·50	..	1·20	..	..	..	0·48	0·29	2·95

NOTE.—The extent of rain is not completely shown by this statement; and the record of columns 5, 6, and 7 is incomplete as regards the intervening stations. In cases where the register shows no rainfall the place is left blank.

(*Paper No. 2860.*)

"Note on the Flood-Discharge of the Tansa Catchment-Area."

By WILLIAM JOHN BIRD CLERKE, B.A., C.I.E., M. Inst. C.E.

IN reference to a Paper on "The Tansa Works for the Water-Supply of Bombay," and to the discussion which took place thereon,[1] the following note may possess some interest.

On the 20th of July, 1894, at 8.30 A.M., the water in the Tansa Lake rose to R. L. 408·15, the top of the dam being 408·00. This gave a depth over the crest of the waste-weir, which is 1,650 in length, of 3·15 feet, and over the top of the remainder of the dam, 6,150 feet in length, a depth of 0·15 foot. With a coefficient of 0·7, the discharge over the waste-weir would thus be 34,500 cubic feet per second. The top of the dam is rough, and the coefficient for the film of water going over it would be small, so that the discharge passing over the 6,150 lineal feet of dam would not add much to the discharge by the waste-weir, probably not more than 500 cubic feet per second. The total flood-discharge would therefore be about 35,000 cubic feet per second. This flood is equivalent to a discharge of 1·04 inch per hour from the whole catchment-area, 52·5 square miles, or 1,040 cubic feet per second per 1,000 acres, or 62·5 cubic feet per minute per acre.

The levels of the water in the lake during the period referred to were:—

19th July	6 P.M.	R. L.	405·16	20th July	9.30 A.M.	R. L.	408·00
20th ,,	6 A.M.	,,	406·20	20th ,,	12 noon	,,	407·70
20th ,,	8.30 A.M.	,,	408·15	20th ,,	6 P.M.	,,	407·30

(waste-weir R. L. 405)

The rainfall registered at the site of the Tansa dam was, between 6 P.M. 19th July and 6 A.M. 20th July, 6·25 inches, and between 6 A.M. 20th July and 6 P.M. 20th July, 5·63 inches. There is no record to show the intensity of the rainfall for any short space of time during these periods. Previous observations indicate that the rainfall at the site of the dam cannot be regarded as an index of the general rainfall on the catchment-area.

[1] Minutes of Proceedings Inst. C.E., vol. cxv. pp. 12 *et seq.*

(*Paper No. 2826.*)

"The Prevention of Silting in Irrigation Canals."

By Robert Greig Kennedy, Ex. Eng. P.W.D., India.

One of the most important and at the same time most difficult conditions to ensure in the construction of an irrigation canal, is that no silting shall take place in it. The observations upon which the results described in this Paper are founded were made upon a portion of the main canal of the Bari Doab canal-system and extended over about 90 miles of its lower reaches. This canal discharged at a maximum rate of about 1,700 cubic feet per second, and included about twelve distributing channels which had carrying-capacities ranging between 30 cubic feet and 250 cubic feet per second. The Bari Doab canal-system is specially valuable for observations of the kind under consideration, because its channels have assumed permanent sections by silting or scouring, and all the sites the data of which will be hereafter discussed had silted beds, often 2 feet or 3 feet deep, deposited during many years of steady flow. No silt was ever cleared away from these reaches, and therefore for a considerable time the silt-transporting power in each has been just sufficient to carry all the sediment brought down; and each reach could have carried neither more nor less than this amount under the given conditions of width of bed, depth of channel and velocity of flow. It has been invariably found that the form of the cross-section thus arrived at is nearly rectangular, the sides being vertical and of fine sediment, and the bed horizontal and of coarser sand.

Thus by observation of the various widths of bed, depths of channel and mean velocities of the stream at each site under normal conditions, means are afforded of discerning how these three factors must be varied among themselves to ensure that no bed-silting shall take place. When this is attained no trouble will arise from side-silting, which consists only of the finer particles, and which takes place, as a rule, only when weeds are allowed to grow upon the edge of the canal. During variations in supply, the thickness of the silted bed was found to vary slightly through

a few inches. The mean velocity of the stream at each reach was derived from the known "full supply" discharge and the measured cross-sectional area of the channel. According to the system of distribution adopted, each distributary was as far as possible always discharged with its full supply, the total discharge of the canal being only sufficient to provide at one time for say nine out of the twelve minor channels; so that usually, neglecting loss by absorption, the sum of the discharges of the distributaries open at any time was equal to the supply in the canal.

In these lower reaches of the canal the amount of silt carried for any given discharge was more or less constant all the year round, though it was by no means so at the head. The extra amount of mud in the river-water during summer was deposited chiefly in the upper reaches in which the velocities of the stream were least; but it was again picked up and carried forward when the cold weather pure water came down; so that the farther reaches of the system were about equally turbid all the year round, except when an excessive flood in the river brought down a different kind and colour of silt. Thus the canal-system may be said to have been in a state of silt equilibrium, all the sediment being practically carried through the very numerous outlets of the distributaries into the water-courses, from which all necessary clearances were made by the cultivator. In other words, the total amount of silt carried by the usual full supply in the canal is equal to the sum of the amounts carried into and forward by the distributaries flowing at the time. All the data now to be detailed refer to these "full supplies," which are somewhat greater than the average discharge, and less than the flood discharge. In all the channels the full supply will bear a more or less constant ratio to the average. The average discharge might equally well have been taken, but the results obtained will be much more useful if they are directly applicable to the full supply required.

Observations were made at thirty sites, data for which are given in Table I of the Appendix. Each was known by long local experience to have been in a state of permanent regime, the canal having been flowing for years on its self-silted bed. Such permanency had been attained only by long prior remodelling and change of slope. Of the thirty points which are plotted, *Fig. 1*, with depths as ordinates and mean velocities as abscissas, five (marked ×) are for reaches in which the alterations had been comparatively recent, and the bed had therefore not yet quite reached

its limit. These points, as was to be expected, all lie somewhat to the left of the full-line curve, which may be taken as representing the average result.

Two points (marked ⊙) refer to another canal, the "Katora," but neither was observed for the full-supply discharge. The true point about midway between them will, however, very nearly coincide with the corresponding one upon the curve drawn for the Bari Doab Canal.

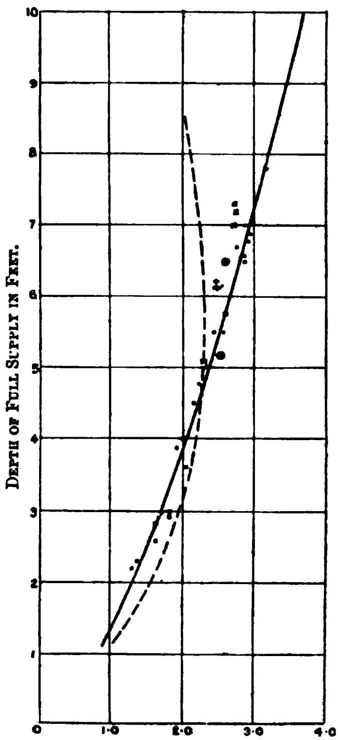
The tabulated data in Table I, Appendix, show that the various channels are very dissimilar as regards the ratio of width to depth, which varies between about 15 and 4. Notwithstanding this, however, the results when plotted are quite as consistent as could be expected in the circumstances, so that apparently the bed-width has no place in the equation connecting the depth (d) and the mean velocity (V_o). The five points, for example, with depths between 3·9 and 5·0 inclusive, are quite consistent, although the ratio $\frac{b}{d}$ varies between 3½ and 12. This seems to show clearly that V_o is a function of d alone, and it is found that the equation is approximately expressed by the empirical expression

$$V_o = c\,d^m = 0{\cdot}84\,d^{0{\cdot}64},$$

and it is from this that the curve has been delineated.

This mean velocity V_o may be called the critical velocity, being that at which for the given depth d silting is just prevented; so that in order to avoid silting in

Fig. 1.



MEAN VELOCITY OF FULL SUPPLY. FEET PER SECOND.

Curve for sections having the same discharge and slope D = 150 c′; S = 0·25; N = 0·0225, — — — —.
Curve $V_o = 0{\cdot}84\,d^{0{\cdot}64}$, ————.

NOTE.—The points marked × are for reaches where the water-level has lately been raised and the silting has not yet reached its limit, *i.e.*, the mean velocity is less than it will ultimately be.

The points marked ⊙ are for the Upper Sutlej Canal system.

RELATION OF "CRITICAL" MEAN VELOCITY (V) TO DEPTH (d) FOR FULL SUPPLY, PLOTTED FOR SITES WHERE A PERMANENT REGIME HAS BEEN ARRIVED AT BY SILTING OF THE BED.

any canal-system, the mean velocity of the stream must not be kept constant in all the channels, but must be increased with the depth according to the above law. V_o is also evidently the least mean velocity for which new channels must be designed, and at which they can be maintained. When the soil permits, a greater velocity than V_o may be given, but never a less; and in the case of very sandy soil, V_o is the only mean velocity which can permanently obtain. On different canal-systems, the values of c and m, in the equation $V_o = c\ d^m$, may vary slightly, though from what follows it may be anticipated any such variation will be but small.

The case of a channel to carry 150 cubic feet of water per second, with a slope of 1 in 4,000, and with the value of N in Kutter's formula for mean velocity = 0·0225, has been taken, and numerous possible cross-sections, each fulfilling the above conditions, have been worked out with different depths of channel, widths of bed, and mean velocities of the stream. The resulting depths and mean velocities have been plotted on the same diagram, and a dotted curve drawn through them. For all depths less than 4·7 feet, this new curve lies on the right of the critical velocity curve, showing that the proposed velocity would be here greater than that required, and scouring would result. At the depth 4·7 feet, the two curves cross, that is to say, the channel would at this point just carry its silt, and at a greater depth than 4·7 feet the velocity becomes less than V_o, and silting would take place. This particular curve, drawn for a discharge of 150 cubic feet per second, may be taken as typical of the most usual cases in its alignment as regards V_o, but each discharge would have a different curve, and with certain data it is even possible that for small depths the curve might lie to the left of the V_o curve, and then cross to the right instead of the reverse, as here delineated. In the case shown by the curve, silting would be cured by decreasing the depth; in the rarer but possible one the cure would be to increase the depth. In cases in which the slope is quite insufficient the curve would lie wholly to the left of the V_o curve, and silting could then be minimised (as afterwards shown), but could not be prevented. With very steep slopes, on the other hand, the curve would lie altogether on the right of the V_o curve, and scouring would then be unavoidable, and modified only by the nature of the soil.

Table II in the Appendix shows for given discharges the necessary minimum velocities and slopes for three different depths of full supply, and covers the usual range of design in India.

From this it will be seen that, especially in the cases of small channels, the greater the depth the steeper must be the slope; or, in other words, when the slope is fixed and insufficient, there is an advantage in most cases in widening the bed and decreasing the depth. This is only true, however, within certain limits, as will be shown below; and as already noted there may be certain unusual cases in which the depth should be increased instead of diminished. The Author's experience shows that silting in small channels has frequently been cured by merely widening the bed.

Sediment in a flowing canal is kept in suspension solely by the vertical components of the constant eddies, which can always be observed in any stream, boiling up gently to the surface. From the sides also, some such eddies may occur to a much smaller degree, but any such must be for the greater part horizontal, and of no silt-supporting power. In order, therefore, to obtain an expression for the silt-supporting power of the stream, it may safely be assumed that the quantity of silt supported will be proportional to the width of the bed, all other conditions remaining the same. It must also vary with the velocity of the stream V, say as V^{n-1}, since the greater the velocity the greater must be the force of the eddies, which become zero when the velocity is zero. There is a third variable, the depth, but this could affect neither the number nor the force of the eddies. The amount of silt supported in a stream may therefore be expressed by AbV^{n-1}, where A is some constant unknown. But whilst thus supported, the silt is being moved forward at velocity V, so that the amount of silt transported will be equal to AbV^n. It is here presumed that all sediment is in suspension, but there is doubtless a small portion of the heavier silt simply rolling along the bed. This amount would vary as bV, instead of as bV^n; so that the value of n to include the rolling silt will be somewhat less than it would be if the suspended silt alone were considered. If it be assumed that the amount of silt supported is proportional to the upward pressure of the deflected currents of water, which varies simply as the square of the velocity, or as V^2, the expression $n - 1 = 2$, or $n = 3$, is arrived at. From these considerations, therefore, and allowing for rolling silt, a value something less than three would be derived for n. It will be shown below that its actual value, deduced from quite independent considerations, is 2·56, or say $\frac{5}{2}$.

In order to obtain an expression for the amount of silt to be carried, let p represent the ratio between the amount of silt carried and the volume of water containing it. The whole

system of canal and distributaries has for years been in steady flow, and in regular intercirculation, so that the water must be of equal turbidity throughout; that is to say, the ratio p is constant. For any discharge, D, the amount of silt carried is therefore expressed by D p, or is, in other words, simply proportional to the discharge.[1]

But it has been shown above that, in the case of each of these self-adjusted channels, $V_o = c\ d^m = 0 \cdot 84\ d^{0 \cdot 64}$. This expression, therefore, not only gives the critical or non-silting velocity for any depth, but also the ratio between the mean velocity and the depth at which the silt ratio p will be constant. It does not from this consideration seem probable that the constants c and m will vary greatly, if at all on different canal-systems. On the other hand, the value of p will vary with the character of the silt, and with its specific gravity. The silt ratio will increase with the depth below the surface; but the value given to p is the average ratio from bed to surface for the whole width between the volume of silt and the volume of discharge in a permanently self-adjusted stream. In the case of a stream of clear water entering a canal and picking up its full amount of silt from previous bed deposits, p then becomes the measure of the erosion of the channel.

The quantity of silt which a self-adjusted channel is able to carry and that which it carries under certain conditions, can now be equated thus:—$A\ b\ V_o^n = p\ D$. But since the channels are nearly rectangular, $D = b\ d\ V_o$, by substituting which, $A\ b\ V^n = p\ b\ d\ V_o$, or $A\ V_o^{n-1} = p\ d$, or $V_o = \left(\frac{p}{A} d\right)^{\frac{1}{n-1}}$, is obtained. This equation is of the same form as that experimentally deduced above, so that the theory advanced is shown to be in accordance

[1] This can be shown algebraically as follows:—Let D represent the full-supply discharge of the main canal, and p its silt ratio, and D_1 and p_1, D_2 and p_2, D_3 and p_3, &c., those of the smaller channels. Since all the silt and supply is carried forward by the distributaries—

$$D\ p = D_1\ p_1 + D_2\ p_2 + D_3\ p_3 + \ \&c. \quad . \quad . \quad . \quad . \quad (1)$$

and

$$D = D_1 + D_2 + D_3 + \&c. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

With this value substituted for D, (1) becomes—

$$D_1 (p - p_1) + D_2 (p - p_2) + D_3 (p - p_3) + \&c. = 0 \quad . \quad . \quad (3)$$

If p, p_1, p_2, &c., are not all equal, some of the factors $(p - p_1)$, $(p - p_2)$, &c., must, therefore, be negative, and some positive; that is to say, some of the smaller channels carry a greater, and some a smaller, quantity of silt than the main canal, the depth, breadth and velocity in which are all greater than in the minor channels. This is manifestly untenable, and hence the silt ratio cannot but be constant throughout the system, and the amount of silt carried cannot but vary directly with the discharge.

with observed facts. The equation $V_o = c\,d^m = 0\cdot84\,d^{0\cdot64}$ is therefore identical with $V_o = \left(\frac{p}{A}d\right)^{\frac{1}{n-1}}$, so that $\frac{1}{n-1} = m = 0\cdot64$, or $n = 2\cdot56$, that is to say, the silt-transporting power of a stream varies as its mean velocity raised to the $2\cdot56$th power, or approximately as $V^{\frac{5}{2}}$. Both p and A must be very small fractions, and vary together with the character of the silt carried in different canal-systems.

The rate at which silt is deposited, when the mean velocity falls from any cause below that necessary to prevent settlement and to carry the full quanity p, can be found as follows:—Calling x the quantity of sediment which the stream can carry at the mean velocity V, the quantity carried at the "critical velocity" V_o for the given depth of channel being p, and the carrying power varying as $V^{\frac{5}{2}}$, it follows that $p : V_o^{\frac{5}{2}} :: x : V^{\frac{5}{2}}$, or $x = p\left(\frac{V}{V_o}\right)^{\frac{5}{2}}$. As, however, the supply channel is presumably n permanent regime, and carries its proper quantity p, the fraction of sediment deposited will be—

$$p-x, \text{ or } p\left(1-\left(\frac{V}{V_o}\right)^{\frac{5}{2}}\right).$$

The values of $\frac{p-x}{p}$, corresponding with several values of $\frac{V}{V_o}$, are given in the Table below, which shows how rapidly silt settles as soon as V falls below V_o:—

$\frac{V}{V_o}$	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
$\frac{p-x}{p}$	1·00	0·996	0·983	0·951	0·899	0·823	0·722	0·592	0·429	0·233	0·00

Another case, curious in its result, is that presented by a channel in designing which sufficient slope to prevent silting in some degree is unobtainable. The cross-section at which the stream will silt least, and therefore cost least in maintenance when sufficient slope is unobtainable, is determined as follows:—The feeder canal or river being assumed to carry its proper quantity p, the portion of the silt deposited as above for any velocity V and depth d, is—

$$p - x = p\left(1-\left(\frac{V}{V_o}\right)^{\frac{5}{2}}\right) = p\left(1-\left(\frac{V}{c\,d^m}\right)^{\frac{5}{2}}\right).$$

This expression is a minimum when the expression $\frac{V}{c\,d^m}$ is a maximum. In the case of a rectangular channel, where $D = b\,d\,V$, $\frac{V}{c\,d^m}$ becomes $\frac{D}{c\,b\,d^{m+1}}$, which again for any given discharge D is a maximum when $b\,d^{m+1}$ is a minimum, that is to say, $b\,d^{1\cdot 64}$. From all the possible cross-sections, therefore, giving the required discharge with the available slope, that one which gives the least value for $b\,d^{1\cdot 64}$ must be selected. In general this will give a comparatively small depth; but in the case of larger channels, at any rate, this will not be less than is quite usual in canal design.

The case is a common one in which, at the head of a canal, the question arises as to the relative quantities of silt deposited, with very turbid water in the river, at high and low discharges; and in which there exists the option of discharging at a greater rate than is needed for the irrigation requirements, the surplus being disposed of by escapes farther down the canal. For the low discharge let the data be D_1, d_1 and V_1; and for the higher D_2, d_2 and V_2; and the silt ratios in the river at both p_1, presumably greater than p which the canal can carry when the channel has finally adjusted itself. The quantity which can be carried at the discharge D_1 is $p\left(\frac{V_1}{c\,d_1^{\,m}}\right)^{\frac{5}{2}}$, and therefore the quantity which will be deposited will be $p_1 - p\left(\frac{V_1}{c\,d_1^{\,m}}\right)^{\frac{5}{2}}$.

The total amount of sediment deposited at the discharges D_1 and D_2 respectively will then be—

$$D_1\left(p_1 - p\left(\frac{V_1}{c\,d_1^{\,m}}\right)^{\frac{5}{2}}\right);\ \text{and}\ D_2\left(p_1 - p\left(\frac{V_2}{c\,d_2^{\,m}}\right)^{\frac{5}{2}}\right).$$

As a case in point, it can be shown that if $p_1 = 2\,p$, and the width of the canal bed is 200 feet, the amount of silt deposited in the canal with a depth of 7 feet is 1·69 time that deposited with a depth of 5 feet; and in general, by actual trial it is seen that except for very low discharges, the second of these expressions is greater than the first. It is therefore erroneous to increase the discharge in a canal-head during heavy floods, on the assumption that at its increased velocity the stream more than carries off the excess of silt brought in.

The Paper is accompanied by a tracing from which the *Fig.* has been prepared.

[APPENDIX.

APPENDIX.

TABLE I.—DETAILS OF SELECTED SITES.

Channel.	Full Supply in Cubic Feet per Second. (D).	Bed-width in Feet. (b).	Depth of Water for Full Supply. (d).	Mean Velocity for Full Supply. (V_o).
Bari Doab Canal—				
M.B.L. 2 miles above Bhuchar [1]	1,250	70	6·5	2·81
Just above Bhuchar Fall [1]	940	66	5·7	2·55
At Jaman [1]	940	66	5·5	2·55
Above Lulliani Bridge [1]	700	61	5·0	2·33
„ Bhambha [1] „	650	48	5·5	2·40
„ Gandian [1] „	390	36	4·8	2·25
Bari Doab Canal—				
Raja. heads, Chabhal Rajbaha [1]	85	16	3·0	1·70
Amritsar [1] „	120	14	4·0	2·00
Doda [1] „	70	12	3·0	1·80
Bhuchar [1] „	220	22	4·5	2·15
Gilpan [1] „	75	14	3·0	1·70
Kanha [1] „	65	15	2·6	1·60
Lulliani [1] „	65	14	2·8	1·60
Minor heads, Athilpur Minor [1]	33	11	2·2	1·30
Chunian [1] „	26	8	2·3	1·40
Bari Doab Canal observed in 1894.				
M.B.L. above Ralliali Rapid [2]	1,700	86	6·8	2·90
„ Thriawal [2] „	1,700	85	7·0	2·86
„ Doburji Raja. head [2]	1,700	84	6·9	2·91
„ Fatteghar Rapid [2]	1,500	80	6·6	2·83
„ Doda Rapid [2]	1,250	68	6·7	2·75
Raja. heads, Turkwind Raja. [2]	142	18	3·9	1·90
Raiwind Raja. [2]	138	18	3·6	2·04
Channels in which the silting of the bed is not complete.				
Bari Doab Canal—				
M.B.L. above Kathunangal Rapid [3]	1,700	86	7·3	2·71
„ Jethowal Rapid [4]	1,700	91	7·0	2·70
„ Tarn Taran Rapid [5]	1,500	76	7·2	2·74
„ Bhuchar Rajbaha [5]	1,250	83	6·1	2·47
„ Bhuchar Fall [5]	940	81	5·1	2·28
At Sohalfoot Bridge [5]	1,250	82	6·2	2·46
On Upper Sutlej Canals.				
Katora Canal near Head [6]	633	50	5·2	2·52
„ „ „ „ [7]	924	55	6·5	2·59

[1] Selected channels in which silting has come to its limit.
[2] No alterations made in water-levels or sections for many years, silting complete.
[3] Crest raised in 1891.
[4] Rebuilt in 1889.
[5] Crest and water-levels raised in 1893 spring.
[6] Taken July, 1892.
[7] Taken July, 1893.

TABLE II.—MINIMUM LONGITUDINAL SLOPES OF, AND VELOCITIES OF FLOW IN, CHANNELS, REQUIRED TO PREVENT SILTING FOR GIVEN DISCHARGES AND FOR VARIOUS DEPTHS OF FULL SUPPLY.

Calculated for N = 0·02375. (Kutter's Formula.)

Discharge in Cubic feet per Second.	For Maximum Probable Depths.			For Moderate Depths.			For Minimum Probable Depths.		
	Depth in feet.	Minimum mean Velocity, V_o.	Minimum fall per 1,000.	Depth in feet.	Minimum mean Velocity, V_o.	Minimum fall per 1,000.	Depth in feet.	Minimum mean Velocity, V_o.	Minimum fall per 1,000.
10	2·1	1·30	0·50	2·0	1·30	0·48	1·8	1·21	0·43
25	2·5	1·51	0·43	2·4	1·46	0·37	2·2	1·39	0·34
35	2·8	1·63	0·39	2·6	1·55	0·34	2·4	1·46	0·31
50	3·1	1·74	0·34	2·9	1·66	0·31	2·6	1·55	0·29
75	3·4	1·85	0·32	3·1	1·74	0·29	2·9	1·66	0·27
100	3·7	1·94	0·31	3·3	1·82	0·28	3·0	1·70	0·26
125	4·0	2·04	0·30	3·6	1·91	0·27	3·2	1·77	0·26
150	4·2	2·10	0·29	3·7	1·95	0·26	3·4	1·85	0·25
175	4·3	2·13	0·28	3·9	2·01	0·25	3·5	1·88	0·24
200	4·5	2·20	0·27	4·0	2·04	0·24	3·6	1·91	0·23
250	4·8	2·26	0·26	4·2	2·10	0·24	3·8	1·98	0·23
300	5·0	2·35	0·26	4·5	2·20	0·23	4·0	2·04	0·22
350	5·3	2·41	0·25	4·6	2·23	0·23	4·2	2·10	0·22
400	5·5	2·50	0·25	4·8	2·29	0·22	4·3	2·13	0·22
450	5·7	2·56	0·25	5·0	2·35	0·22	4·4	2·17	0·21
500	5·8	2·62	0·24	5·1	2·38	0·22	4·6	2·23	0·21
600	6·1	2·66	0·24	5·3	2·44	0·21	4·8	2·29	0·21
700	6·3	2·73	0·23	5·5	2·50	0·21	5·0	2·35	0·20
800	6·6	2·80	0·23	5·8	2·62	0·21	5·2	2·41	0·20
900	6·8	2·86	0·22	5·9	2·61	0·20	5·3	2·44	0·19
1,000	7·0	2·92	0·22	6·0	2·64	0·20	5·4	2·47	0·19
1,500	7·8	3·12	0·21	6·8	2·85	0·20	6·1	2·66	0·19
2,000	8·5	3·31	0·20	7·3	3·00	0·19	6·6	2·80	0·18

(*Paper No. 2812.*)

"Deep-Water Quays, Newcastle-upon-Tyne."

By Adam Scott, Assoc. M. Inst. C.E.

The Newcastle quays, of which a plan is shown in Fig. 1, Plate 8, extend for a length of about 4,620 feet along the north bank of the River Tyne, from the swing-bridge at A, eastward to a point marked B at the mouth of a small stream called the Ouseburn.

The Old Quays.—About the year 1840, the quay shown in section in Fig. 2, Plate 8, between the 60-ton crane and the Swirle, was erected by Mr. Anderson, the then river engineer to the Corporation. A portion of this quay, which was built in front of an older one, still remains; and with the exception of it and the old sloping walls at the London and the Hamburg Wharves, all the quays have been constructed since 1866—prior to which date they extended from the old Tyne Bridge to the east end of the Rotterdam Wharf, a length of about 3,345 feet. The depth at low-water alongside these quays varied between 2½ feet and 5½ feet, though in one section next the Tyne Bridge, where the wall was undermined, it varied between 10½ feet and 13 feet.

Deeper quays and more accommodation being required for the increasing traffic in the port, the extension of the quays eastward from the Rotterdam Wharf was commenced in 1866, and between that year and 1874 was carried to the Ouseburn. The quays constructed between 1866 and 1877 were carried out by Mr. J. Lamb, the property surveyor to the Corporation. In 1866, a contract was let for 570 feet of quay, Fig. 3, to be constructed on piles, and designed for a depth of water of about 12 feet at low-water, which was thought to be sufficient for the requirements of the port. But owing to a proposal of the Tyne Commissioners to increase the depth of the river-channel to about 20 feet at low-water, the Corporation subsequently decided to have the quays built to allow for a depth of about 22 feet at low-water. It thus became necessary to alter the contract then being carried out, and to strengthen a length of 177 feet of the wall which had

already been built. To meet the altered conditions, another and stronger section, Fig. 4, was adopted, but after about 49 feet of the wall had been completed the work was stopped, as it was considered to be too costly. The cost of these lengths of piled quays seems to have been about £200 per lineal yard. The advice of Mr. James Abernethy and of the late Mr. T. E. Harrison, Past-Presidents Inst. C.E., was obtained, and, as proposed by Mr. Harrison, it was decided to adopt cast-iron cylinders, sunk under atmospheric pressure, for the substructure of the quay. Fig. 5 shows a section of the work as carried out between the termination of the piled quay and the Ouseburn. The cylinders are 5 feet in diameter, and are placed 25 feet apart from centre to centre along the quay. Over the intervening spaces masonry and brick arches are turned, springing from cast-iron beams which connect the front and back cylinders and carry the superstructure, which consists of ashlar facing with concrete backing and a granite coping. Between the front cylinders metal sheet-piling was driven in the form of a segment and terminating at the level of low-water. Before the dredging in front of this quay had reached the intended depth the wall began to show signs of weakness, and in 1875–76 a large portion of it was strengthened by a trench of concrete at the back, 11 feet 6 inches wide, carried 8 feet below low-water. The cost of this additional work was £45 8s. per lineal yard. Lengths C and K, Fig. 1, next the Tyne bridge, and at the 80-ton crane (Figs. 6 and 7), were begun in 1872–73, and are similar to that at the Ouseburn. They cost about £123 and £217 per lineal yard respectively.

Experience having shown that this wall was too weak for so great a depth of water, an alteration was made before the completion of the contract next to the Tyne bridge. The metal sheet-piling was done away with, and a continuous row of cylinders was substituted—6-feet circular cylinders being placed 13 feet 9 inches apart from centre to centre, and elliptical cylinders between them. The back cylinders were 5 feet in diameter and behind the 6-feet circular cylinders. It was soon found that the elliptical cylinders were too weak under the pressure, and that it was unsafe for men to work in them. Another change therefore became necessary, and Mr. Lamb proposed to omit the elliptical cylinders and the metal beam and arch, and to try a close row of 6-feet circular cylinders in front, the back cylinders remaining as before, but tied to every alternate front one by a wrought-iron band passing round both. This proposal, Fig. 8, was adopted in a new contract, January 1875, for the greater part of length D, Fig. 1, in front of

the Custom House, and carried out in that portion between Lombard Street and the 60-ton crane. The same method was adhered to in the construction of the grain-warehouse quay, G, Fig. 1, and Fig. 9, which was completed in 1879. Between the years 1866 and 1879 about 3,357 lineal feet of wall were built at a total cost of about £239,323. In addition to this sum a large amount has been expended on the purchase of property for quay improvements, on the formation of streets, on the quayside railway, and on sheds and cranes. The cranes on the quays comprise one 80-ton hydraulic crane, one 60-ton steam-crane and six locomotive steam-cranes. There is a double-storey shed with hydraulic cranes, a single-storey shed, and several open sheds.

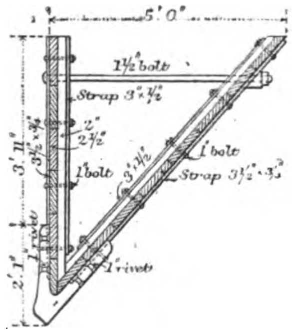
The New Quay-Wall.—In February 1886 a slip occurred in the quay built in 1840, Fig. 2, on the east side of the 60-ton crane. Mr. P. J. Messent and Mr. W. G. Laws, the City Engineer, jointly reported upon the rebuilding of the quay, and recommended the construction of a deep-water quay to give a depth of about 20 feet at low-water of spring tides, the foundations to be constructed by sinking well-monoliths of concrete. They advised that this plan should also apply to the reconstruction of all the old quays which required renewal. The recommendations of the engineers for restoring the fallen part having been approved, the Council decided that the work should be carried out by their own workmen.

The wall, Fig. 10, consists of a substructure of large monolithic blocks, each (with one exception) 30 feet long, 20 feet wide and 37 feet deep, with a well 20 feet by 10 feet and walls 5 feet thick. The caissons were 37 feet deep, sunk to an average depth of about 32½ feet below low-water, and were filled with concrete. They were set about 2 feet apart, and the spaces between them were filled with concrete to a certain depth. On these blocks a masonry and concrete superstructure was built. Three monoliths, covering about 94 lineal feet, were sunk for the restoration of the fallen work, which was completed between 1888 and 1890. It was afterwards decided to continue the work westward to the 60-ton crane, a further length of about 188 feet, requiring five blocks 30 feet long and one closing-block, No. 9 monolith, Figs. 11, 22 feet long, which was finished between 1890 and 1893.

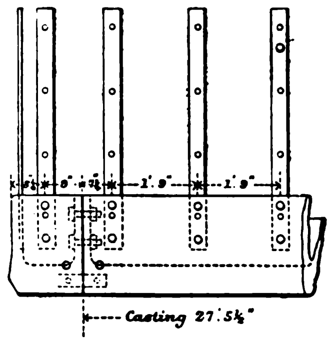
The operations for rebuilding the fallen portion were commenced in May, 1888, and only a narrow space of ground was enclosed so as to interfere as little as possible with the quay-side traffic. The site was cleared by the removal of the old wall and piles, so far as they were within the line of the new wall and could be found without diving or dredging. The temporary staging piles

were driven behind the line of the new wall. The curb, *Figs.* 12, of the monolith was 6 feet in height, the cutting-edge being an iron casting of V-shaped section 2 feet 1 inch deep with vertical wrought-iron straps attached, and timber lining. The cast-iron toe was made in four parts, which were bolted and riveted together at the corners. The timber for lining the curbs was nearly all obtained from the piles which formed the foundations of the old wall. The piles, which were principally of beech and elm, were fairly sound, though they had been in use about fifty years. In constructing the curb the castings were first set and bolted temporarily together, after which the timber lining was fitted and bolted upon it. The finished curb was let down into position in four parts, which were bolted together at their corners in the bottom. Sometimes a little concrete was put into

Figs. 12.



Section.



Elevation.

the curbs before they were let down. The bottom was levelled to receive the shoes, and was made up, where necessary, to 3 feet or 4 feet above low-water level. Straps were put across the corners on the inside at the top of the curb to prevent the sides bulging out. The curbs being set level were filled with concrete, and on this the sides, 5 feet thick, were built all round. The shutters for concreting were 3 feet deep, and were carried on 9-inch by 3-inch standards. After each 3-foot filling, sufficient time was allowed for the concrete to set. When the monoliths had been built to a height of 9 feet or 12 feet above the top of the curb, they were stripped and sunk, the interior being taken out by grab-dredgers, until the top was 3 feet or 4 feet above low-water level. The standards and shutters were then again fixed, the sides built up another 9 feet or 12 feet, and the caisson

sunk, and so on, alternately building and sinking until the full height of 37 feet was attained, with the toe of the curb fairly entered into the hard ballast, which lay at about 31¾ feet to 33 feet below low-water level, leaving the top of the monolith at a permanent level of about 4½ feet above low-water level. The ballast was generally found to be very hard, the grab often bringing up large crusts resembling concrete. The sinking blocks were not guided or suspended in any way, but were left entirely free, and were thus liable to work a little out of place. Sometimes a block would heel over considerably on one side, but could generally be righted again by the excavation. The forward movement was considerable in the cases of the first three blocks, and the other six blocks were set back in line to allow for this; but they did not go forward more than about 1½ inch to 6 inches. To prevent this movement as far as possible, weight was added along the whole front of the blocks by depositing a bank of copper slag and old ashlar in the river. The greater part of these stones was afterwards lifted out, and the slag was dredged away.

The sinking of the monoliths was a difficult and anxious process, owing to the nature of the strata to be passed through and the danger to the street behind arising from a bed of quick-sand and mud, between 19 feet and 20 feet thick, which caused a large additional amount of excavation, rushing in and sometimes filling up the well to a depth of several feet. Owing to this undermining process, the street in some places showed signs of cracking and sinking, and the staging of the first section also moved forward slightly and had at one part to be shored up. In the staging of the second section, longer piles were used, the front ones and every alternate back one being driven to or about the hard ballast. The construction of the timber stagings was let by contract. To protect the 60-ton crane from being undermined, a row of sheet-piling was driven across the end of the new work. Old rails and kentledge-blocks were used as weights in sinking the caissons. In the first section, the greatest weight put on a block was 220 tons; for the second section, 150 tons of special kentledge-blocks were cast, and in addition to these there were at the last 200 tons of rails, making the heaviest load 350 tons.

The monolith having sunk to its permanent position, a little copper slag was put into the bottom of the wells and roughly levelled. Small bags of concrete were then packed by the divers all round the toe under the curb, and the wells were filled with 1 to 7 concrete, with a little rubble thrown in. The concrete was lowered through the water in small skips, which were

generally allowed to touch the bottom before the concrete was freed, and were then gently raised, and the doors released. It was desirable to keep the surface of the filling fairly level, to prevent, as far as possible, the cement from running into holes and forming deep pockets of soft deposit which would never set. This, however, in some instances, did occur. When the wells were filled to within 2 feet or 3 feet of the top, the water was generally lifted out, and the remainder of the hearting was put in dry, deep pockets of unset cement being cleared out.

A series of timber struts was inserted down the centre of the wells of the first three blocks during the process of sinking, and was removed as the concrete filling was brought up, but in the next length of the work these struts were dispensed with. The front sides, facing the river, of the first three monoliths, had a batter of 1 in 30, but all the other blocks were built vertical.

The spaces between the monoliths were piled at the back and front, and the material within was cleared out, by divers and by a small grab made for the purpose, to a depth, in the centre, of about 27 feet below the top of the block. This process was a tedious and troublesome one, owing to material running in from the back or front, or from both. The filling of these spaces was also put in through the water, the concrete being 1 to 5, excepting a little at the bottom, which was generally 1 to 3.

On this substructure was erected the upper wall, consisting of sandstone ashlar facing backed with 1 to 5 cement-concrete, to which some rubble was added, and finished with Aberdeen granite coping 4 feet × 1 foot 9 inches. Weep-holes were left at intervals in the wall. The face of the wall has a batter of 1 in 12. The fenders are of American Rock elm. The ashlar stones from the old wall were, as far as possible, redressed and used in the new work, the rest of the ashlar being brought from local quarries. To add to the strength of the monoliths, pieces of old rails about 11 feet long were bent and laid in the concrete across the corners at intervals of about 6 feet in the height of the structure.

The concrete for the monolith walls, for the spaces between the monoliths, and for the backing of the superstructure, was gauged 1 to 5. The concrete hearting was 1 to 7. The ballast for concrete was obtained chiefly from the Tyne, and was used in its natural state. The cement-mortar was gauged 1 to 3, and the grout was of pure cement. The Portland cement was manufactured in the locality and was of fine quality.

The filling behind the new wall was principally of ashes, but a little of the excavated material was placed at the back of the first

length of wall. Most of the excavation from the back of the old wall and from the wells was sent to sea in hoppers. Two locomotive steam-cranes were employed, capable of lifting 5 tons at 30-foot radius on a single-part chain, and of travelling, slewing and derricking, all the motions having two speeds. These cranes were furnished with Wild single-chain grab dredgers of 1 cubic yard capacity, one being a half-tine grab and the other a close bucket for sand. Only one of these cranes was required for the first section.

Owing partly to the narrowness of the space available for carrying on the work, the material had to be handled twice or even more often. Few men could be employed, and much of the work was tidal and was carried on at night, which tended to increase the cost. This has amounted to about £196 per lineal yard, including the filling behind the wall, but exclusive of the principal plant, the temporary staging, the paving and the dredging.

Mr. W. G. Laws was the engineer for the work, Mr. P. J. Messent being the consulting engineer. The Author acted as the resident engineer.

The Paper is accompanied by two photographs and three tracings, from which Plate 8 and the *Figs.* in the text have been prepared.

[APPENDIX.

APPENDIX.

Approximate weight (estimated) of wall per lineal foot—

	Tons.	Cwt.
Substructure	45	5
Superstructure	6	18
Total	52	3

Approximate weight (estimated) of monolith, 30 feet × 20 feet × 37 feet—

	Tons.
Iron	21
Wood	6
Concrete	1,332
Total	1,359

The weight of ironwork in the 30-foot × 20-foot curb was between 20 tons and 22 tons.

The side castings for the 30-foot shoe were 27 feet 5½ inches long, and those for the ends 20 feet 4 inches long, and in the second section these weighed respectively about 4 tons 3 cwt. and 3 tons 6 cwt.

The weight of ironwork in nine curbs was about 184 tons.

	£.
Cost of castings, straps (riveted) and bolts for nine curbs as delivered at the quay works from the foundries by contract, excluding fitting, about	1,209
„ of erection of stagings	705
„ „ first crane and grab	870
„ „ second crane „	957
„ „ small special grab (3 cubic feet capacity)	42
„ „ castings per ton	£4 12*s.* 6*d.* and £6 2*s.* 6*d.*
„ „ straps per cwt.	10*s.* and 7*s.* 6*d.*
„ „ bolts, &c. „	14*s.* 2*d.* and 12*s.* 9*d.*

(*Paper No. 2804.*)

(*Abridged.*)

"Machinery for carrying out Sea-Works."

By William Eyre Kenny, Assoc. M. Inst. C.E.

The Author had collected the materials for this communication before the Paper on the same subject, by Mr. Walter Pitt,[1] reached him, and, in order to avoid repetition, he has omitted some descriptions of machinery, and has adapted his remarks to the point of view of the executive engineer rather than to that of the designer of plant for sea-works. The subjects treated are:—

Meteorological instruments and special apparatus for carrying out marine-engineering surveys; building- and dredging-plant; and the application of transmitted power to harbour plant.

Meteorological Instruments, &c.

When sea-works have to be carried out under circumstances which do not admit of assistance from meteorological reports, it will be found convenient and economical to include in the office equipment a standard mercurial barometer, an aneroid barometer, a set of wet- and dry-bulb thermometers, a self-registering anemometer (preferably of the tube pattern), a rain-gauge and a self-registering tide-gauge. By the aid of regular observations with such instruments at New Plymouth and Gisborne Harbours, N.Z., and by carefully watching the drift of clouds, atmospheric effects and the colour and motion of the sea, it was found possible to make fairly reliable weather predictions, and very slight loss was suffered from unforeseen storms, although several abnormally severe gales occurred. At Gisborne it was found that when the diver reported the water to be exceptionally clear, a gale from seawards almost invariably occurred within twenty-four hours. The meteorological observations should form a part of the regular duty of an assistant engineer, and preferably of the officer who is executing, or has executed, the marine surveys, for these are so

[1] Minutes of Proceedings Inst. C.E., vol. cxiii. p. 2.

dependent on the weather that it is necessary for him to become conversant with the local conditions relating to them.

Apparatus for carrying out Marine-Engineering Surveys. — An exact method of determining the position of an isolated rock or shoal is that by means of three theodolites on shore, so placed that well-conditioned triangles can be obtained, the observations being made simultaneously at given signals from a launch or boat. When the position of a buoy is being fixed, care should be taken that the boat is as nearly over the mooring as possible in order that the anchor may be picked up in case of the buoy breaking away; and when a mean position is being indicated, the prevailing winds and currents must be considered, and the approximate bearing and distance of the mooring noted to facilitate its recovery in case of the chain parting.

Measurement of Distances.—In the setting out of marine works, or in the making of a survey in which extreme accuracy is desirable, steel bands $0 \cdot 30$ inch $\times$ $0 \cdot 025$ inch in cross-section will be found useful. They should be marked every 100 feet, joined up in lengths of 500 feet with cliphooks, and kept wound on drums immersed in lime-water. When in use the drums should be mounted in winches at the stern of a launch, with dynamometers attached to show the strain on the band, and when winding in the band it should be passed through a tank of fresh water to minimize corrosion. For river-work these bands can be divided into 10-foot lengths or coupled up in shorter lengths if necessary. To obtain exact measurements between river-banks, or between structures, the method adopted at the Forth Bridge will be found to give accurate results.[1] When soundings are required, without extreme accuracy, at regular intervals, ordinary Russian hemp-ropes in 500-foot lengths, graduated about every 10 feet, will in some cases be found useful; and if two, or preferably three, points have been fixed by observation on the line, the error due to sag and stretch may be approximately eliminated. These ropes should be attached to a small "can-buoy" at points about 250 feet apart, and stretched as tightly as possible with a tackle or winch.

Current-Meters.—To be thoroughly satisfactory for use in sea-work, a current-meter should be strong, easily managed, fairly accurate and capable of being used from a boat, or small vessel, in a seaway. When nothing better is available, an ordinary "log-chip" will be found useful, and may be adjusted to various depths.

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[1] "The Forth Bridge," *Engineering*, Feb. 28, 1890, p. 12 of reprint.

Care must be taken, by revolving it slowly when dropping it overboard, to avoid its presenting its edge to the current. The Author has found under certain circumstances an ordinary Walker log, with the blades enlarged and the dials graduated accordingly, and fitted with an adjustable float (a table of corrections for slip at various speeds, constructed from experiments in currents of known velocities, being used), gives fair results, but time is consumed in making the observations. In river-work and in smooth water more delicate instruments can be used, and those are to be preferred which communicate their readings electrically to the surface, or to the shore.

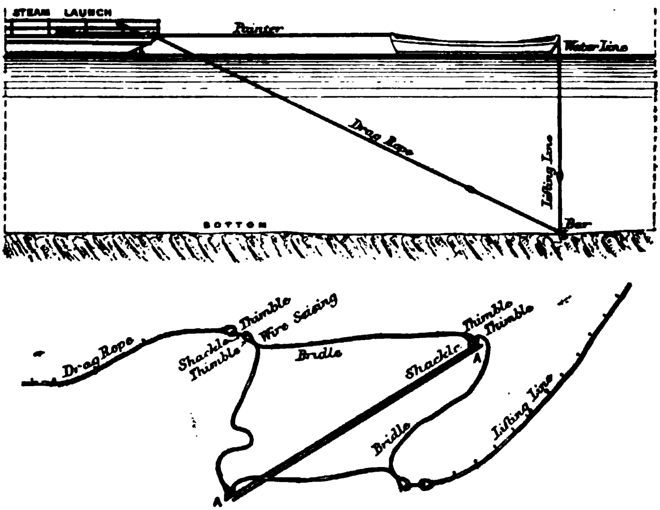
The movement of shingle or sand on a beach or bank can be ascertained by depositing brick, or slag, of approximately the same specific-gravity as that of the materials forming the beach, and by a diver or otherwise periodically examining their changes of position. When a diver is employed for the purpose, he should descend vertically beneath the launch, and on reaching the bottom should release a float. The bearing and position of this float when it reaches the surface will give approximately the mean direction and the mean speed of the current, and further information may be obtained by the float being released at different depths.

Sounding-Apparatus.—A flexible copper wire-rope, graduated in feet, will be found to be an efficient sounding-line. At sea, the soundings in ordinary weather should be taken alternately from either quarter, but in bad weather it will be possible to sound only from the weather quarter. A derrick should be rigged over each quarter, and the wires should be rove through snatch-blocks, lashed to their heads, and the sounding-line should be wound on a drum actuated by hand- or steam-power. In greater depths than 15 fathoms the vessel requires to be almost stationary in order to get an accurate sounding. For obtaining samples from the bottom, small grabs attached to the lead, and caused to close on touching the bottom by the release of a spring, will be found more efficient than an arming of tallow.

Apparatus for detecting shallows.—The apparatus shown in *Figs. 1* was constructed and tried by the Author in 1891, and has rendered very useful service during the execution of marine surveys. It consists of a railway bar, A A, 25 feet long, weighing about 300 lbs., to each end of which two bridles are attached. From each end of the bar one of these bridles is connected to the drag-rope drawn by the steam-launch and the other to the lifting-rope which is suspended from a boat towed by the launch. The bridles

and other portions of the gear likely to chafe are made of ⅜-inch chain, the drag-rope of 4-inch Manilla, and the lifting-rope of 4-inch Russian hemp, graduated in feet. The boat's painter is attached to the weather-quarter and the drag-rope to the lee-quarter. A man on the launch adjusts the drag-rope, and slackens it if the bar comes into contact with a rock, and two men are stationed in the boat, the duty of one being to hold the lifting-line and in case of a touch to telephone the depth as shown by it, and of the other to assist in lifting the bar when it fouls a rock, and to slacken the boat astern after the necessary observation has been made, and the drag has been sufficiently raised to pass over

Figs. 1.



the obstruction. When searching for isolated pinnacle rocks in deep water, the bar is suspended at a depth of 7 fathoms; in depths not exceeding 11 or 12 fathoms, it is allowed to follow the bottom, and continuous soundings can then be taken with it and telephoned from the boat. During the first trial of the apparatus for continuous sounding, leads were used simultaneously, but many shallows were shown by the drag, which escaped the intermittent action of the leads. The apparatus was approved by the Colonial Marine Engineer of New Zealand in 1891, for use on a hydrographical survey. It is more efficacious than a long chain dragged by two launches, which, moreover, is useless for continuous sounding.

Examination of the Bottom.—When a rocky bottom is overlaid with between 5 and 10 feet of sand or mud, reliable borings cannot be made from a launch or a boat, owing to the violence and varying direction of their motion in a seaway, and the Author has found that it is more satisfactory to employ a diver to measure the depth of the sand. A good diver will penetrate a thickness of between 10 and 15 feet of sand or mud, partly by digging and partly by pricking with a suitably pointed rod, in from ten to fifteen minutes. A heavy lead is dragged along the bottom by the launch, and the diver follows it by means of a stray line; when the lead is in position, the diver is telephoned and takes the boring.

Marine Surveys, &c.—A steam-launch possesses great advantages over a boat, for work can be carried on by its means in weather which would render it impossible from a boat, and less time is lost in moving from place to place. If the surf on a bar or beach renders the use of a steam-launch inadmissible, a whale-boat, 30 feet long, 7 feet wide and 2 feet 9 inches deep, propelled by six oars, and steered by an oar over the quarter in addition to the rudder, fitted with a triangular metal centre-board, and rigged with jib and two French (standing) lugs, will be found a good weatherly craft, and large enough for a diver to work from.

Block-yard Machinery and Plant.

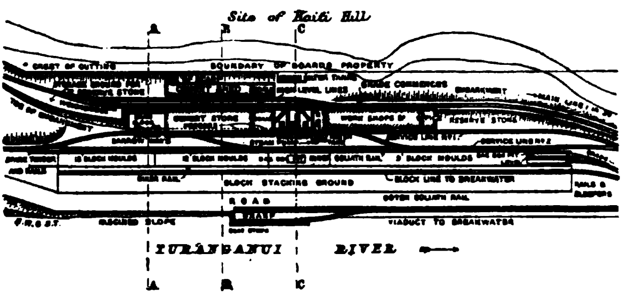
In the execution of harbour works in new countries, a uniform gauge should, if possible, be adopted for all the railways in connection with them. In New Zealand the 3 feet 6 inches gauge has been found convenient and fairly economical, unless a connection with very distant quarries through rough country is necessary, but then nothing less than a metre gauge should be used.

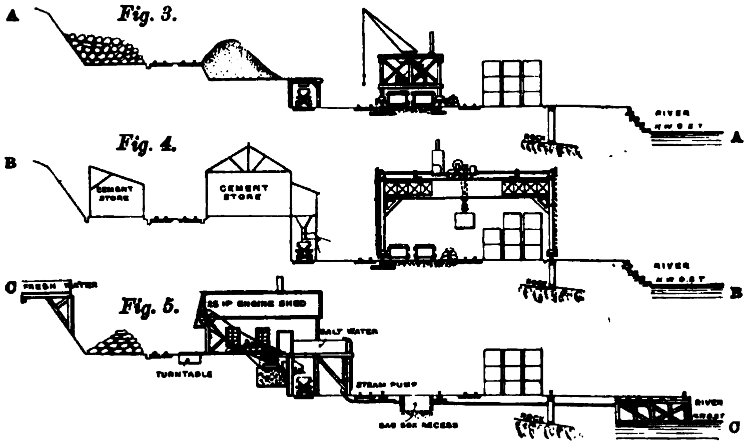
A plan and cross-sections of the Gisborne block-yard, as constructed by Mr. John Thomson, B.E., Engineer to the Gisborne Harbour Board, are shown in *Figs. 2, 3, 4* and *5*. The sand-floor, capable of holding 670 tons of sand, was situated at the north-west end of the yard, at a height of 9 feet above the level of service-line No. 1, over which a timber frame-work was built to the same height as the sand-floor, and connected with it by barrow ways. Along these the sand was wheeled in barrows and dropped into skips on a trolly standing on the rails beneath the framework.

The floor of the cement-shed was 14 feet above the same service-line, and the crusher platform was built up to the same level. Above the cement-shed was a simple system of cranes for handling the casks, and two hoppers were provided fitted with

slides, worked by two levers, to cut off the requisite quantity of cement, their capacity being adjustable. Stone for the blocks was brought from quarries $3\frac{1}{4}$ miles distant, and was tipped on to the crusher platforms, or run down to the yard or breakwater for use as displacers. Upon the crusher platform three Blake-Marsden 15-inch × 9-inch stone-crushers and a 25-HP. semi-portable engine

Fig. 2.





Scales—*Fig.* 2, 260 feet to 1 inch; *Figs.* 3, 4 and 5, 65 feet to 1 inch.

BLOCK-YARD AT GISBORNE HARBOUR—PLAN AND SECTIONS.

were installed. Each crusher discharged into a pair of shoots fitted with measuring shutters, and these emptied into two skips on service-line No. 1, the shoots being so arranged that both skips were filled at the same time without moving the trolley. The cement-shoots were arranged in a similar manner. The skips, after receiving sand, cement and broken stone (in the order named), were drawn under the mixer by horses.

The block-moulds, which were constructed from a design by the late Sir John Coode, with wooden and cast-iron cores for the lewis holes, were arranged in groups of the various sizes in pairs on level concrete floors.

The inner Goliath crane-rail was also used for the mixers. The gauge of the Goliath line was 55 feet, and of the mixer line 18 feet 6 inches, both lines being laid with steel-flanged rails on longitudinal sleepers, 15 inches × 15 inches and 12 inches × 12 inches respectively, the Goliath rails weighing 86 lbs., and the mixer rails 56 lbs. per yard. It is very important in the use of wide-gauged cranes that especial care should be taken in laying the rails, to secure solidity and accuracy of line and level. The Author has noticed several cases in which slight negligence of these points has caused an unnecessary amount of wear and tear of the ground-wheels and travelling-gear, in addition to general straining of the structure.

For filling bag-boxes a hole was sunk in the middle of the yard, into which the box was lowered by the Goliath. Mixer No. 2 then travelled over it, and, after filling the bag-box, passed on. The Goliath next lifted the bag-box on to a block-truck ready to be run down to the breakwater. In filling the 30-ton bag-box, both mixers were employed, the concrete from No. 2 mixer being passed on by the Goliath in a 15-ton bag-box, which required to be gradually opened when adding this semi-liquid mass of concrete to the similar material already in the larger bag-box. Salt-water was used for making the concrete, and it was pumped from the river by a Cameron pump into a 6,000-gallon cast-iron tank, placed at the same level as the crusher platform, from whence it gravitated into the mixer-tanks as required. Fresh water was used in the boilers.

Suggested Improvements.—Although the general arrangement of this yard proved to be fairly convenient, some improvements may be suggested on minor points. Time would be saved if, instead of the barrow-ways and hand-barrows at the sand-floor, self-righting skips, hung on travelling or overhead rails, were used. A small locomotive for drawing the skips containing dry materials to the mixers would also have been much more convenient and expeditious, and more economical than horses, and the wear and tear on the yard would have been considerably diminished.

Concrete Mixers.—Both mixers were of the Lee type,[1] which, mounted on timber frames, travelled over the rows of block-moulds

[1] Minutes of Proceedings Inst. C.E., vol. cxiii. p. 4.

and bag-box recesses. The average output of each, when block-making, was about 68 cubic yards per day of eight hours, and the best day's work was 82 cubic yards, which, however, could have been increased if necessary. The average coal-consumption for each mixing was about 8·7 lbs., and, with four block-moulds worked at the same time, seventeen men and two boys were employed at the sand-floor, the cement-shed, the crusher-platform, the moulds, the mixer, the displacers, and in driving trolleys carrying skips. Twenty revolutions of the barrel were found amply sufficient to ensure thorough mixture.

The cost of block-making, including stacking, ranged between 19·5*s.* and 21·7*s.* per cubic yard. When monoliths were being filled up, the mixers discharged into the 15-ton bag-boxes, which were then run down to the breakwater, lifted by the Hercules crane, and emptied. If small quantities of concrete were required at the scar end, it was delivered in skips holding 1 cubic yard.

A few trifling improvements upon the mixers may be suggested, although they worked admirably, the gearing being well designed and the workmanship excellent. The ordinary turnover-skips cause an appreciable loss of cement on windy days, when the material is being tipped into the mixer hoppers, which could, no doubt, be remedied by the use of hopper-skips. The engines should also be protected from the grit and dust which is always flying about by inclosing them in a plain iron casing provided with doors. The slides which close the hoppers on the top of the mixers are difficult to withdraw, and this was effectually remedied by inserting a Λ-shaped piece of sheet-iron across the opening above the slide in order to diminish the pressure upon it. After about two and a half years' use, the mixer barrels began to require patching. This might be obviated by lining the barrels with a removable thin steel segmental lining, held by screws passing through the barrel-plates and screwed up from the outside. A modified form of Lee mixer is shown in *Fig. 6*, which would allow the concrete to run out more freely than those used at Gisborne.

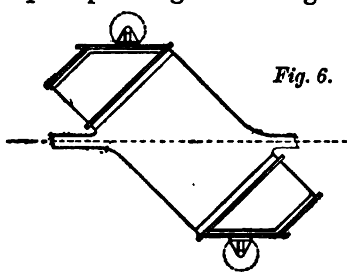


Fig. 6.

Scale, 6 feet to 1 inch.

At New Plymouth Harbour four half-yard stationary Messent mixers were employed. They were so placed that trolleys carrying skips could pass under them to receive the mixed charges, a jib-crane being used in the yard to

tip the concrete into the moulds. The cost of blocks so made has been stated to be between 23*s.* and 23*s.* 4*d.* per cubic yard.

Mode of testing Mixers.—With the object of testing the comparative efficiency of mixers, the Author conducted some experiments, by putting into the mixers coarse white sand, equal in quantity to the sand used when making concrete, fine brown sand, equal in quantity to the cement used when making concrete, and ordinary broken stone, and mixing them sometimes as dry materials, and at others with the addition of the usual proportion of water. By examining samples of the mixture taken after 5, 10, 15, 20, and 25 revolutions, a good idea of the performance of the machine may be formed. Experiments conducted in this way showed that the minimum number of revolutions after which good concrete could be turned out were:—8 to 10 revolutions with the Messent mixer; 15 to 20 revolutions with the modified Lee mixer, *Fig. 6*; and 20 to 25 revolutions with the ordinary Lee mixer. The Author has not applied this test to a continuous mixer; but, excepting for large bags or monolithic work, he considers the intermittent mixer more suitable in every respect for block-making. The speed at which the mixer is revolved is important. If too rapid, some of the materials will be driven by centrifugal force into remote corners without mixing; if too slow, there will not be sufficient incorporation per revolution, and time will be lost; and the speed is variable according to the materials used.

Most suitable type of Mixer for Sea-Works.—For large works two structures are advisable, somewhat similar to those at Gisborne, each with two half-yard Messent mixers, so arranged as to be driven either alternately or together, with a crane for hoisting the dry materials. The Messent mixers require less height to work in than those of the Lee type, and can be more easily constructed to pass the Goliath. For bag-work, and for supplying concrete for work *in situ*, a mixer of the Punchard type, so raised as to allow the block-trucks carrying the bag-boxes to pass under it and to be quickly filled, would make the mixing-plant complete.

Mixing by hand is inapplicable in countries where wages are as high as in New Zealand; but with Chinese or other very cheap labour, the method of mixing described by Mr. G. F. Deacon,[1] in the discussion on Mr. Pitt's Paper, previously referred to, might be adopted, provided that the work were supervised by Europeans.

[1] Minutes of Proceedings Inst. C.E., vol. cxiii. p. 47.

Block-yard Cranes.

At New Plymouth Harbour, a Goliath crane with a hydraulic lifting cylinder was employed, capable of lifting blocks weighing 35 tons. A set of three-throw pumps was fitted to supply the hydraulic pressure, and the load was lifted on the bight of a chain. The crane travelled on four wheels, two of which were drivers, and the gauge was about 50 feet. Its range of lift was limited, and the stacking of the blocks in the upper tier required two successive operations, the gear having to be altered before making the final lift. At Timaru, Omaru, and Napier harbours revolving diagonal jib-cranes for stacking and loading up in the yard were employed, similar to those used also for block-setting at those ports.

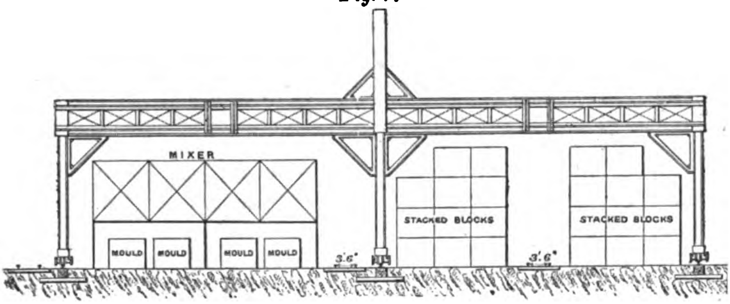
The Goliath Crane at Gisborne.—At Gisborne Harbour the performances of the Goliath crane, described in Mr. Pitt's Paper, were satisfactory. This crane with its load weighed about 85 tons; the ground-wheels were of solid cast-steel, and were without springs. Purchased in England in 1886 for £1,750, it had cost £2,165 when ready for work at Gisborne. Whenever, as at Gisborne, it is important to keep the design of a blockyard compact, a crane of the Goliath type is cheaper in first cost, and is as efficient as any other crane. It occupies the minimum amount of space while at work, whereas a revolving crane would have required a working radius of at least 30 feet, and a clearway of at least 22 feet.

A crane of the Goliath type should be capable of travelling quickly with its full test-load, and all, or any, of its motions should be capable of gearing-in simultaneously or separately. The speeds of working in slow gear should be for lifting about 10 feet per minute, for travelling 40 feet per minute, and for traversing 50 feet per minute, and in quick gear these speeds should be multiplied by 2½. If weights exceeding 19 tons are to be worked, a Matthews hydraulic brake should be fitted. Ample boiler-power should be supplied, and means for lifting fuel and supplying water should be fitted. In order to diminish the chance of synchronizing the periods of vibration, a donkey-pump or an injector is preferable to a feed-pump, worked by the main engine. If the weight of the crane exceeds that of the Gisborne Goliath, wheels with steel tires and cast-iron centres should be fitted. If the machine has to be landed in lighters from an open roadstead, no separate part should weigh more than 7 tons.

New type of a Goliath Crane.—In some yards of restricted length the Goliath is traversed over to a second set of moulds and block-

stacks, but it would be found more convenient to obviate this by an arrangement such as that shown in *Fig. 7*, intended to carry four half-yard Messent mixers, in which these can pass under the crane with the minimum amount of dismantling. In order that the lifting machinery may have freedom to travel with its load over the whole length of the machine, the upright frames at the ends and at the centre are constructed in two portions, which are braced together by the iron beam below, to which the wheels are fitted, and by a horse-shoe shaped stiffener above, of sufficient height to allow the traveller to pass beneath it. The boiler and machinery are mounted respectively upon the two platforms carried by the two separate portions of the machine. The Goliath travels upon twelve wheels, of which four are fitted to each frame.

Fig. 7.



Scale, 30 feet to 1 inch.

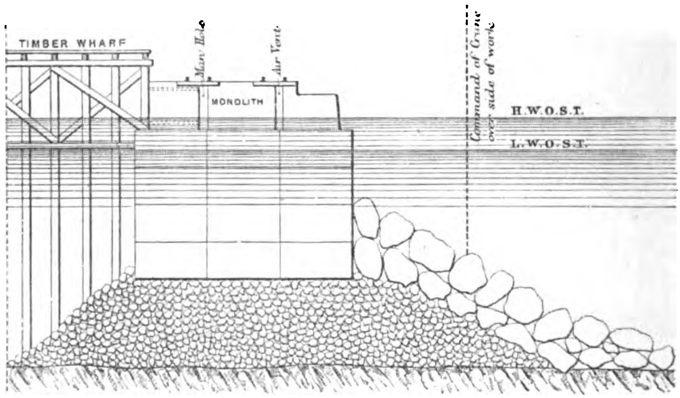
One such mixer would easily keep up the same supply of blocks as two of those at Gisborne. The probable cost of such a crane, with a gauge of 105 feet and capable of working 30-ton blocks, would be from 75 to 80 per cent. more than the Gisborne Goliath.

Block-setting Plant.

On several harbour-works in New Zealand "diagonal-jib-cranes" have been employed for block-setting, capable of lifting between 30 and 40 tons, at a radius of from 30 to 35 feet. They were mounted on low trucks, travelling on sixteen single-flanged wheels, arranged over two 3 feet 6 inches gauge lines, laid with flanged rails weighing 56 lbs. per yard. The speed at which these cranes could work was slow when compared with that of a Hercules, but they were otherwise satisfactory when employed on breakwaters constructed on the inclined-block system (*Figs. 8* and *9*). The blocks on this system were generally set on a rubble

mound approaching to within 3 or 4 fathoms of low-water of spring tides. On the other hand, when employed on regularly bonded work, founded on bag-work laid on the rock, they had not sufficient forward command, and they lowered the blocks too unsteadily to give satisfactory results. Owing to the imperfect overlap, or bond, the bottom blocks in some cases were cracked and broken on account of their having to resist the whole shearing force of their own weight and of the mass above them. The consulting engineer at New Plymouth breakwater, which in design was somewhat similar to the outer portion of that at Gisborne, reported that the crane used at New Plymouth for bag-work could operate

Fig. 8.



Scale, 30 feet to 1 inch.

NAPIER BREAKWATER—CROSS SECTION.

only 21 feet 2 inches ahead, whereas the revolving Hercules recommended by Sir John Coode could work at from 45 to 50 feet ahead, and thus allow some of the bags to set before being loaded.

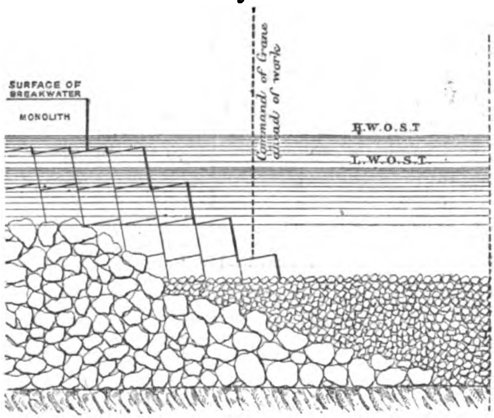
The New Plymouth crane cost, inclusive of repairs, about £3,940. A point generally in favour of the diagonal-jib-crane is that it is likely to be useful after the construction work is finished. It is a fairly efficient machine, in cases where the design of the work is compatible with its command, and probably more so than the rectangular crane, but its small command limits its applicability to one class only of breakwater work.

Rectangular Cranes.—The Titans[1] used at Kurrachee, Madras, and Mormugao, were rectangular machines (*i.e.*, cranes with

[1] Minutes of Proceedings Inst. C.E., vol. cxiii. p. 9.

motions in three co-ordinate directions) of an early type, and they were stated during the discussion on Mr. Pitt's Paper to have given satisfactory results. During the early stages of the work at New Plymouth Harbour, a Titan was also used. It was capable of setting blocks weighing 35 tons about 20 feet ahead of the finished work. The row of blocks on the weather-side had to be lifted by the crab-tackle between the girders, a second tackle from an overhanging arm being then used to swing them out to a sufficient distance. Eight ground-wheels were provided, arranged in pairs under the end uprights of the truck, the travelling motion being mainly transmitted by shafting and worm-gear. The general work performed by this crane was satisfactory, but the machine

Fig. 9.



Scale, 30 feet to 1 inch.

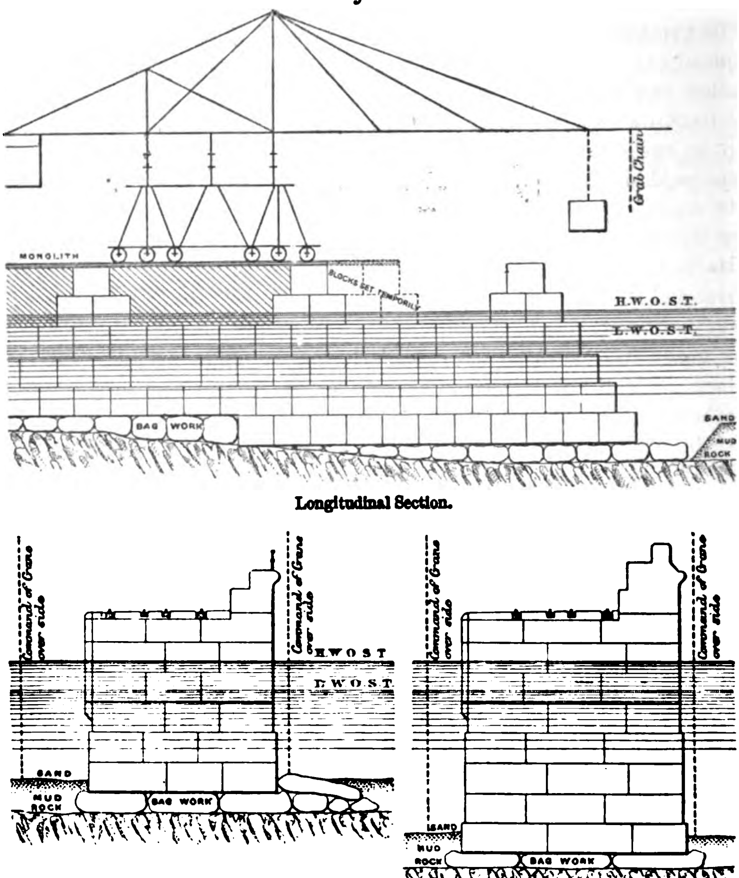
NAPIER BREAKWATER—LONGITUDINAL SECTION.

was unsuitable for the cross-section of the breakwater, and it was abandoned in favour of the low-truck revolving diagonal-jib-crane mentioned above. From some data obtained by the Author, it appears that block-setting with this machine cost between 4*s*. 6*d*. and 5*s*. per cubic yard. At the termination of the work this Titan was dismantled, taken to pieces, and stored. Its approximate cost had been between £3,000 and £4,000. Nearly all the rectangular machines possess the disadvantage that they are unable to travel with their load, which reduces their command, and there is small scope for their employment when their work as block-setting machines is finished.

Gisborne Hercules Crane.—The Hercules at Gisborne (*Figs. 10*), which could radiate through about 22½° on either side of its

centre-line, was constructed entirely of iron and steel, and was capable of lifting 30-ton blocks at a radius of 62 feet. Cross-sections of the breakwater showing the command of the crane on either side are shown in the *Figs.* The distance from the end of

Figs. 10.



Longitudinal Section.

Cross-sections, showing command of Crane.

Scale, 32 feet to 1 inch.

GISBORNE BREAKWATER.

the finished work to the centre of the load at the extreme radius was 46 feet. The gauge was 15 feet and the clearway under the truck 13 feet 7½ inches. Power was supplied to the Hercules by a vertical boiler 10 feet high and 5 feet in diameter, with Galloway

tubes, and a pair of engines with 10-inch cylinders and stroke of 14 inches. The load was lifted on 1⅛-inch chain, one part being a hauling part, which coiled on to a spirally-grooved barrel, 5 feet long and 4 feet 6 inches in diameter, reeved so that there was no alteration of height when the radius was being changed. The lifting chain was well supported over the jib by two of the Pitt tumblers. The total lift was slightly over 50 feet, and enough chain was coiled on the barrel to lower the block 41 feet 6 inches below the rail-level.

Racking motion was communicated to the block-lifting carriage by an endless steel hawser, 4½ inches in circumference; but this was seldom used, the change of position being made by moving the machine bodily. The degree of accuracy of movement attained by travelling in this manner proved to be quite as great as that attained by racking. A 1-yard "Wild single-chain dredger" was arranged to work at any point along the jib. When the radius was being changed, the lifting and racking motions were both in gear, and were so arranged that no change of height took place. Block-lowering was controlled by a Matthews hydraulic brake, which is an indispensable fitting, and the grab and racking motions by ordinary strap brakes. A brake on the slewing motion would have been useful. The gearing was so arranged that all, or any, of the motions could be performed simultaneously, the levers actuating the clutches being all brought together to one platform. The crane ran on twelve double-flanged wheels, the treads being 2 feet 6 inches in diameter, arranged in groups of three under the ends of the lower truck girders, two wheels in the rear group on each side being coupled as drivers. The crane travelled easily and well with the full working load at the extreme radius, and on several occasions passed over bad portions of the line without any trouble. The total length of the wheel-base was 31 feet, the machine being designed to pass round curves of 460 feet radius. The total weight of this crane was about 181 tons, and its operation showed that, in cranes with similar wheel-bases and wheel-pressures, springs are not absolutely necessary, but no doubt lessen wear and tear. This crane was capable of lifting a considerably greater number of blocks than the divers could deal with. The ballast was composed of old railway iron, and small concrete blocks. An ordinary davit with the fall led to a winch end on the engine shaft, answered satisfactorily for lifting fuel. When working in windy weather, a flexible speaking-tube was used for communicating with the driver.

The cost of block-setting below water per cubic yard at Gis-

borne for an average day's work, say eight blocks, or 80 cubic yards, was as follows:—

	s.
Craneage and labour in the blockyard	0·42
Transport of blocks to the pier-head . . .	0·17
Craneage at the pier-head	0·57
Labour (including two divers)	0·93
Total . . .	2·09

Or about 2s. 1½d. per cubic yard.

The cost of block-setting in the lowest course varies with the roughness of the bottom.

The large overhang of this machine was most useful when the monolith sections were being built up, but for depositing dredgings its inability to radiate through a complete circle caused great inconvenience. When dredging out the foundation, from 80 to 150 cubic yards per day of stiff mud had to be lifted, and either dropped over the weather side, or into trucks standing below the crane, and this necessitated their travelling twice the distance that, with a revolving crane, would have been sufficient. When, however, cement or other small loads were required to be discharged from shipping, the dredger chain was used, and at this work the Hercules proved itself as quick and handy as a locomotive 5-ton crane. If its gauge had been 18 feet 6 inches instead of 15 feet, it could have been constructed to revolve at an extra cost of about £600. It was purchased in England for £5,300 in 1887, and when erected in New Zealand ready for work had cost about £6,560. It has rendered most efficient service, and, with the exception of the lifting-chains, has suffered very slight wear.

General Remarks.—A block-setting crane must have capacity for rapidly dealing with the heaviest load likely to occur during the progress of the works, and both for the purposes of dredging the foundations down to the solid, and for bag- and block-setting work, must have absolute command over the scar end and weather side. The truck must possess sufficient clearway to allow the rolling stock in use to pass under it, and the crane should be adapted for employment on other works of various designs after the completion of the work for which it was specially constructed. The revolving Hercules is undoubtedly the type of crane which most efficiently fulfils these conditions. Revolving jib-cranes, rectangular machines, and radiating machines, are all useful on works of certain designs, but the revolving Hercules is capable of carrying out all and any style of sea-work up to the limit of its greatest reach.

Mode of Attachment to Blocks.—For blockyard and above-water work the ordinary T-ended lewis-bars passing vertically through the block, and 6 feet apart, were used at Gisborne, and were found quite satisfactory; little or no gain in speed would have been effected by using bars of a more complicated design.

Bag-Setting Plant.—Bag-boxes similar to those described in Mr. Pitt's Paper were used at New Plymouth, Napier and Gisborne. One 30-ton and two 15-ton bag-boxes were found sufficient at Gisborne for all requirements. A plain iron tray was used for depositing small bags weighing between 1 ton and 4 tons, suspended by four chains, two of which were shackled into a slip-link, which was either tripped from the crane or released by the divers. The tipping-box used at La Guaira[1] is useful in cases where very large bags are required, but its use is generally confined to working bags that are beyond the capacity of ordinary cranes.

Floating Plant for Bag- and Block-Setting.—The use of floating-plant for this purpose is usually restricted to depositing random block-, bag- or rubble-work, and it cannot be usefully employed in exposed situations, except during long periods of perfectly smooth weather. An iron steam-punt, capable of depositing concrete bags of between 50 and 60 tons weight, was constructed for New Plymouth harbour, but was never used. The accuracy of its work would probably not have approached that of a crane working on the pier. At Napier an iron hopper-barge was used for depositing the rubble-mound sufficiently far ahead of the superstructure to allow it to become thoroughly settled before blocks were set. For work of this description floating plant is a necessity. An example of a floating self-propelling crane, capable of working in moderate weather, is that constructed by Messrs. Lobnitz & Co., for Pernambuco harbour.[2]

Auxiliary Dredging-Plant sometimes required.

At Gisborne a 7-inch Ball sand-pump was included in the plant, in case the Hercules grab should be unable to keep the foundations sufficiently clear of sand; but it was found that the crane grab could easily accomplish all the dredging required for laying the foundations.

If a quantity of mud or other material that a sand-pump cannot lift has to be removed, one or two single-chain dredgers, mounted

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[1] Minutes of Proceedings Inst. C.E., vol. cxiii. p. 23.

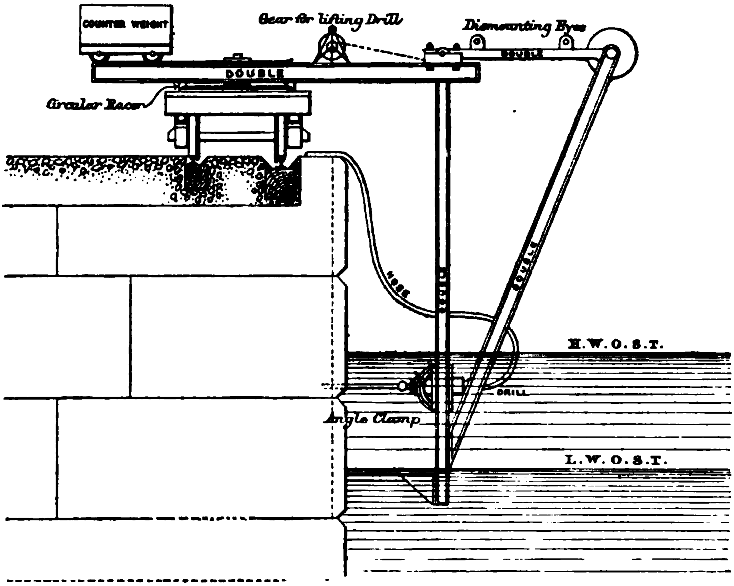
[2] *The Engineer*, vol. lxxiii. 1892, pp. 2, 3, and 6.

on a self-propelling barge, will be found convenient; and if rock has to be dealt with, one or two Lobnitz rock-cutters[1] can be installed on board, as well as the grab-dredgers. If the rock is comparatively soft, and a ladder dredger is available, some of the buckets may be removed and replaced by strong claws; the machine is then capable of doing efficient work.

Plant for carrying out Miscellaneous Work.

Drilling Bolt-Holes.—Much time and labour are often expended in drilling bolt-holes by hand in concrete-work faced with timber,

Fig. 11.



Scale, 8 feet to 1 inch.

or where timber wharves abut against the concrete work. This would be obviated if a machine-tool similar to the ordinary rock-drill were employed, actuated directly by steam from the crane boiler, or by an air-compressor working on the crane, or if an electric, pneumatic, or hydraulic transmission plant were used (*Fig. 11*).

Diving-Gear.—Diving-gear having the regulating-valve in the breast-plate seems to be preferred by divers, and every helmet

[1] Minutes of Proceedings Inst. C.E., vol. cxvii. p. 369.

should be fitted with a telephone or a speaking-tube. Double-acting pumps should be used capable of supplying two divers in shallow, or one in deep water. For work at the scar end of a breakwater at least six dresses per pump should be available, two in use, two under repair, and two in reserve. Shot belts are to be preferred to solid weights on account of their being more readily adjusted and more convenient to the diver.

In works where a staging is required, a self-propelling cantilever carrying a pile-driver is useful. When necessary, it could be constructed to drive all the piles in one bay simultaneously.

The Application of Transmitted Power to Harbour Plant.

The nature of the work to be done by harbour plant gives a considerable opening for the employment of "transmitted power," and any of the systems of transmission, except that by ropes, which are now in general use more or less applicable. In most cases it will be found more convenient and economical to employ the ordinary independent, self-contained steam-machinery; but electricity, water-power, or air under pressure are in many cases applicable. Turbines or Pelton wheels will be found to give excellent results as generators, and hydraulic pressure might be easily transmitted for the purpose of working most of the locomotive, as well as the stationary machinery, employed on sea-works. In applying it to fixed machinery there need be no departure from ordinary practice, but when applied to locomotive cranes and mixers a travel much exceeding that given to ordinary hydraulic cranes would have to be allowed for. If hydraulic pressure were used, the most suitable connection would be by means of a flexible pipe or hose coiled on a drum attached to the crane or mixer, and so geared to the travelling motion that it would take up the pipe or hose as the crane or mixer advanced or retired. Flexible metal tubing may be constructed to withstand a pressure of 700 lbs. to the square inch, as described by Mr. Gilbert Redgrave,[1] and would be suitable for the purpose.

The electrical system of transmission of power is, however, the most applicable and is economical in first cost, especially in cases where water-power is available to drive the generators; and with an electrical installation it also becomes easy to arrange

[1] Report of the British Association for the Advancement of Science, Edinburgh, 1892, p. 870.

lights for use in tide-work or in regular night-work. It will probably be found more convenient than hydraulic power.

The following Table shows the comparative first cost and cost of working of the different methods:—

Method.	First Cost.	Comparative Cost working by Steam.	Comparative Cost working by Water.	Remarks.
	£.			
Hydraulic . .	15,100	1·92	0·25	Includes Hercules.
Shafting . . .	14,300	1·95	0·26	Independent Hercules.
Electric . . .	13,400	2·00	0·29	Includes Hercules.
Pneumatic . .	14,000	2·20	0·32	„ „
Independent .	11,000	1·95	..	„ „

The Paper is accompanied by six drawings, from which the *Figs.* in the text have been prepared.

[APPENDIX.

APPENDIX.

List of Plant for carrying out a Concrete Breakwater in an Exposed Situation, based on the Gisborne Plant purchased in 1886 and 1887. (Quarries 3½ miles from the Works.)

1. *Special Plant used at Gisborne Harbour.* (Maker's prices in 1887.)

	£	s.	d.
Hercules block-setting crane (tested to 40 tons)	6,000	0	0
Goliath travelling-crane (tested to 40 tons)	1,750	0	0
Two Coode concrete-mixers	1,386	0	0
One 30-ton bag-box	250	0	0
Two 15-ton bag-boxes	206	0	0
Twenty tested lewis-bars	45	0	0
Half-yard Wild grab-dredge	106	5	0
Ball sand-pump	750	0	0
Duplicates of wearing parts	226	0	0
Ten block-trucks (tested to 40 tons)	670	8	0
Block-moulds	918	6	0
Total	12,307	19	0

2. *Ordinary Plant used at Gisborne Harbour.*

	£	s.	d.
Three stone-crushers (Blake-Marsden, 15 inches × 9 inches)	583	3	3
25 HP. C.S. engine	562	6	8
Special steam-pump and piping	22	10	0
Cast-iron tanks, &c. (6,000 gallons)	82	10	0
Ten hydrants and surface-boxes	13	9	6
20 tons of cast-iron water-pipes (4-inch)	85	15	8
Galvanised pipes, &c. (328 feet × 3 inches)	19	17	0
India-rubber hose (240 feet × 2 inches × 3 ply)	16	4	8
5-ton steam travelling-crane	460	0	0
10-ton hand-derrick	115	16	0
„ winch	14	10	0
Small „	3	1	8
Ten hydraulic jacks (one 50, three 10, three 6, and three 3 tons)	35	15	9
Twenty-one London blocks (various sizes)	21	2	7
Four single-fluke anchors and chains	23	1	6
Locomotive (four wheels coupled)	450	0	0
Forty-five trucks and trolleys	1,175	0	0
Railway weigh-bridge (12 feet × 6 feet, to 20 tons)	90	0	0
Cement-tester	26	19	3
Forge fittings	14	11	10
Two iron tanks	18	0	0
Carried forward	£3,833	15	4

	£	s.	d.
Brought forward	3,833	15	4
Ten steel 1-yard skips	110	19	4
Three sets of diving gear (double pumps)	497	7	0
Divers' and whale-boats	106	0	0
Duplicates of wearing parts	37	18	4
Small plant, anchors, chains, boats, ropes, forges, benches, turntables, buckets, sledges, machine-tools, &c.	250	0	0
Tools, miscellaneous	150	0	0
Total	4,985	15	0
Abstract:			
Special plant	12,307	19	0
Ordinary plant	4,985	15	0
Total cost of complete plant	17,293	14	0

Rates of Wages at Gisborne Harbour per Day of Eight Hours.

Rank.	s.	d.
Senior foreman	15	0
Foreman fitter	12	0
Drivers, 1st class	11	0
,, 2nd ,,	10	0
Firemen	9	0
Carpenters, 1st class	11	0
,, 2nd ,,	10	0
Blacksmiths	11	0
Foremen, 1st class	10	0
,, 2nd ,,	9	0
Labourers	8	0
Boatmen	8	0
Foreman diver (above water)	11	0
,, ,, (below ,,)	24	0
Divers (above water)	10	0
,, (below ,,)	20	0
Boys	4	0

(*Paper No. 2672.*)

(*Abstract.*)

"Windmills for Raising Water."

By JOHN ALFRED GRIFFITHS, B.Sc., Wh.Sc., Assoc. M. Inst. C.E.

ALTHOUGH the application of power furnished by the wind to industrial purposes has been largely superseded by steam-power, yet there are many places—notably on the great plains of Australia and in other countries where fuel is scarce and where water is not available for the development of power—where the wind can be depended upon to furnish power for purposes which admit of its intermittent application. Thus water pumped during a gale may be stored in an elevated reservoir and used at will for many operations, such as grinding and sawing, in which continuous operation or even constant speed is not essential.

Windmills have of late years been largely manufactured, chiefly in the United States of America, for the purpose of driving reciprocating pumps, usually from a crank on the main axle of the sail-wheel. The design and efficiency of these direct-pumping mills form the subject of this Paper. The mills are generally placed directly over the well on a wooden tower or post. At the top is a turntable with an open centre, through which the pump-rod descends vertically to a reciprocating pump in the well. A horizontal crank-shaft, supported in bearings on the upper movable part of the turntable, is connected to the pump-rod by a swivel joint, in order to permit the rotation of the mill-top necessary for adjusting the sails to the varying horizontal direction of the wind. One overhanging end of the crank-shaft carries the sail-wheel, which is usually between 10 feet and 20 feet in diameter. Sometimes the sail-wheel is on the lee side of the tower, in which case it maintains its direction perpendicular to the wind by pulling the turntable round. In other mills a rudder vane, with sufficient area and leverage to overbalance the sail-wheel, is fixed to the turntable, and the pressure of the wind on this rudder keeps the sail-wheel perpendicular to the wind, but on the weather side of the tower. In some of the larger mills the Meikle auxiliary steering wheel is

employed; but as mills of as great a diameter as 60 feet can be steered by simpler means, this complication is only necessary when the mill drives a vertical shaft in the centre of the tower, as in the older mills. Controlling- and regulating-gear, either automatic or operated by hand, is necessary to stop the mill when the storage-reservoir is full, or for repairs, and also to prevent damage by racing in gales or hurricanes.

If a uniform stream, having a sectional-area of A square feet, of air weighing w lbs. per cubic foot moves with a uniform velocity of v feet per second, the weight of air passing in one second

TABLE I.

ENERGY OF WIND ACTING UPON A SURFACE OF 100 SQUARE FEET.

Velocity of wind.	At Sea-level.	At 1,000 feet above Sea-level.	At 2,000 feet above Sea-level.	Velocity of wind.	At Sea-level.
Miles per hour.	HP.	HP.	HP.	Miles per hour.	HP.
1	0·0007	0·0006	0·0005	31	19·91
2	0·0053	0·0050	0·0046	32	21·90
3	0·0180	0·0168	0·0156	33	24·01
4	0·0428	0·0399	0·0370	34	26·26
5	0·0835	0·0780	0·0724	35	28·65
6	0·1443	0·1347	0·1251	36	31·18
7	0·2292	0·2140	0·1987	37	33·85
8	0·3422	0·3193	0·2966	38	36·67
9	0·4872	0·4547	0·4223	39	39·64
10	0·6683	0·6237	0·5792	40	42·77
11	0·8895	0·8301	0·7710	41	46·25
12	1·1550	1·0790	1·0010	42	49·51
13	1·4680	1·3700	1·2730	43	53·13
14	1·8340	1·7110	1·5900	44	56·92
15	2·2550	2·1050	1·9550	45	60·90
16	2·7370	2·5550	2·3720	46	65·05
17	3·2840	3·0640	2·8460	47	69·39
18	3·8980	3·6370	3·3780	48	73·91
19	4·5840	4·2780	3·9760	49	78·61
20	5·3470	4·9900	4·6340	50	83·53
21	6·1890	5·7760	5·3640	51	88·65
22	7·1160	6·6400	6·1680	52	93·96
23	8·1300	7·5880	7·0480	53	99·49
24	9·2380	8·6220	8·0080	54	105·20
25	10·4400	9·7460	9·0500	55	111·20
26	11·7500	10·9600	10·1800	56	117·40
27	13·1500	12·2800	11·4000	57	123·70
28	14·6700	13·6900	12·7100	58	130·40
29	16·3000	15·2100	14·1300	59	137·20
30	18·0400	16·8400	15·6400	60	144·30

is w A v lbs., and the energy required to start or stop such a stream is

$$w \text{ A } v \text{ lbs.} \times \frac{v^2}{2\,g} = \frac{w}{2\,g} \times \text{A } v^3 \text{ foot-lbs. per second.}$$

It is convenient in connection with windmills to adopt as unit of area 100 square feet, corresponding to a circle of 11·3 feet in diameter, which is about that of the smallest windmills usually employed, and for velocities the unit of miles per hour. A uniform stream, of 100 square feet sectional-area, of air weighing 0·075 lb. per cubic foot, and moving with a velocity of 10 miles per hour, therefore contains an actual kinetic energy of 1,323,267 foot-lbs. per hour, or 0·6683 of an English horse-power, and from these coefficients the energy of any other stream may be calculated. In Table I is given the horse-power of the wind acting upon an area of 100 square feet, and moving at velocities ranging up to 60 miles per hour for places at the sea-level, and up to 30 miles per hour for places 1,000 feet and 2,000 feet above the sea-level. The weight of the air is taken as 0·075 lb. per cubic foot at sea-level, and at 0·070 and 0·065 lb. per cubic foot at altitudes of 1,000 feet and 2,000 feet above sea-level respectively.

The numbers multiplied by the area acted upon, in units of 100 square feet, give the horse-power of the wind passing any windmill at the several velocities.

Windmill Efficiency.

The direct problem may be stated thus: A windmill of area A is acted upon by a stream of air moving at a velocity of v feet per second, and develops energy at the rate of n foot-pounds per second; what is its effect on the wind? The energy of the advancing stream of air is $\frac{\text{A}\,w\,v^3}{2\,g}$ foot-pounds per second, and the departing stream has its energy reduced by n foot-pounds per second, consequently during the passage of the wind through the few inches constituting the axial thickness of the wheel its average velocity must be reduced to v_1, such that

$$\frac{\text{A}\,w\,v_1^3}{2\,g} = \frac{\text{A}\,w\,v^3}{2\,g} - n;$$

or

$$v_1^3 = v^3 - \frac{2\,g\,n}{\text{A}\,w}.$$

The highest net efficiency observed in the Author's experiments, at 7 miles per hour, was 25 per cent., and in this case the velocity of the wind on leaving the wheel would be v_1 such that

$$v_1^3 = \frac{100 - 25}{100} \times v^3,$$

whence

$$v_1 = \sqrt[3]{0 \cdot 75} \times v = 0 \cdot 909\, v.$$

From this it will be seen that the loss of velocity is proportionately less than the loss of energy; thus with the ordinary working efficiency of 10 per cent. or less, the loss of velocity is hardly appreciable and would be most difficult to measure, especially on account of variations in it, amounting sometimes to over 50 per cent., which occur every few seconds.

In designing a windmill for pumping, two things have to be considered, namely the torque, or statical turning moment, and the speed of the wheel in relation to that of the pump. The torque must be made as large as possible, so that the mill will start, though slowly, with the faintest wind containing sufficient energy. The speed of the mill, if without gearing, must not be too fast for the pumps in a small mill or too slow in a large mill; hence the absolute size of the mill is an important element in the arrangement of its vanes. For determining the normal pressure on a surface inclined to the direction of the wind, the Author prefers to use the results obtained by Professor S. P. Langley[1] and Mr. W. H. Dines.[2] Curves showing the most important of these results are given in *Fig. 1.* For the purpose of comparison the curves for $\sin \alpha$ and $\sin^2 \alpha$, representing the older hypotheses, are also shown (in thin unbroken lines). Curves have also been added for three other functions having about the same range and curvature as the experimental lines. The uppermost of these $\frac{2 \sin \alpha}{1 + \sin^2 \alpha}$ is due to Duchemin, and is quoted by Langley as being a very good approximation to his experiments with square vanes. The line for vanes 6×24 inches, presented short edge to the wind, may be approximately expressed by the function $1 - \cos^{10} \alpha$, and the other experiments with vanes $30 \times 4 \cdot 8$ inches, presented long edge to the wind (as in a windmill), are not very different from $\sqrt{\sin \alpha}$.

[1] "Experiments in Aerodynamics." S. P. Langley, Smithsonian Institution, Washington, 1891; abstracted in Minutes of Proceedings Inst. C.E., vol. cvii. p. 546.

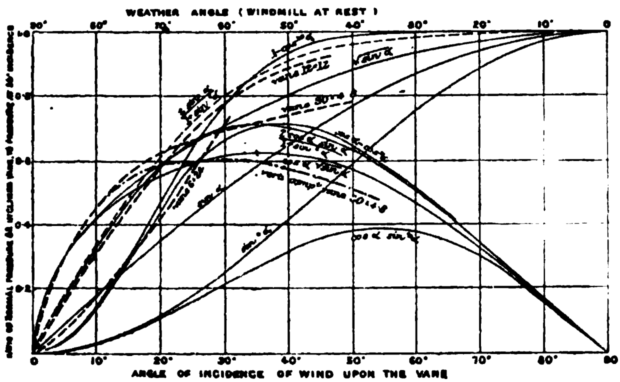
[2] "On Wind Pressure on an Inclined Surface." W. H. Dines, Proc. Royal Society, vol. xlviii. 1890, p. 233.

These curves represent the ratio of the normal pressure on the vane, when its plane is inclined a° to the direction of the wind, to the normal pressure when the same vane is placed with its plane perpendicular to the direction of the wind. The component of the pressure which produces the torque in windmills at rest is equivalent to the vertical component in Langley's experiments, and is represented by the function

$$\cos a \times F(a),$$

$F(a)$ corresponding to Langley's experimental curves or by the arbitrary functions used as approximations. The determination

Fig. 1.



The curves — — — — are derived from Prof. S. P. Langley's results.
The curve — · — · is due to Duchemin.

for each of the functions of the value of a which will make the torque a maximum gives the following results:—

Arbitrary Function.	$\cos a \sin^2 a$.	$\frac{2 \cos a \cdot \sin a}{1 + \sin^2 a}$.	$\cos a (1 - \cos^{10} a)$.	$\cos a \sqrt{\sin a}$.
$a =$	54° 44′ rejected.	35° 16′ square vanes.	38° 7′ long vanes end to wind.	35° 16′ long vanes edge to wind.

If the first function be excepted, the close agreement of the angle of incidence for maximum torque in the others shows that although the shape and aspect of the vane has important influence on the normal pressure, yet the component perpendicular to the wind is but slightly modified thereby. The curves show that although the vanes set short edge to the wind have a slightly higher maxi-

mum torque than those at long edge to the wind, yet for the latter the torque is relatively less affected by a variation in the angle of incidence. From Langley's experiments it appears that the functions are applicable to all velocities of wind between 0 and about 50 miles per hour. The angle between any portion of a vane and the plane of the wheel is termed the weather or weather-angle at that point; consequently to obtain the greatest torque at starting, the weather should be the complement of the best incidence angles, viz., between 70° and 55°. In practice it will be found that the weather is never so great as this, the greatest angle in the examples tested being 43°. When the sail-wheel begins to move, the conditions are altered, as the direction of the wind relative to the moving vane is no longer parallel to the axis, and the angle of incidence is less than the complement of the weather. To retain a good angle of incidence at working speeds the weather must therefore be very much less than that which gives the greatest torque at rest; and as the absolute velocity at any point of the vane increases in proportion to the radius, the best angles of weather must be expected to vary continuously at different points along a radial line.

Let a wind moving at a velocity of v feet per second impinge on an element of a vane at a distance r from the centre of the sail-wheel, turning s revolutions per second, and let γ be the "weather" of the element. Then $2\pi r \times s$ is the absolute velocity, and by the parallelogram of velocities, the relative direction of the wind with respect to the vane makes an angle β with the plane of the sail-wheel, such that

$$\tan\beta = \frac{v}{2\pi r s},$$

and the absolute angle of incidence, a (provided the wind drives the vane), is such that

$$a = \beta - \gamma,$$

so that $$\tan\beta = \tan(a + \gamma),$$

and the weather at various radii of the same vane may be adjusted to make the angle of incidence uniform (or variable according to design) at different radii for any particular relation between v and s. Following Smeaton's practice and putting k for the ratio of the speed of the tips of the vanes of a wheel of radius R to the speed of the wind,

$$k = \frac{2\pi R s}{v}, \text{ and } \frac{v}{s} = \frac{2\pi R}{k},$$

so that $$\tan(a + \gamma) = \frac{v}{2\pi r s} \text{ or } = \frac{R}{k r};$$

and by deducting $a = 30°$ from a series of angles whose tangents are inversely proportional to the radius, a uniform angle of incidence may be obtained all over the vane.

Smeaton,[1] from his experiments on the old-fashioned four-arm windmills of large diameter, gives 2·6 as the best value for k, but in the following experiments with small direct-pumping mills it ranged between 0·65 and 0·923 at the speeds of maximum efficiency in each case. The first systematic attempt to reduce the action of wind on a vane-surface to experimental law was made by Smeaton, whose experiments, published in the Philosophical Transactions of the Royal Society, 1755–1763, are still the most reliable data extant.

Attempts to investigate windmill action for extended periods in the manner so successfully applied to steam-engines fail entirely, for the reason that both the velocity and the direction of the wind fluctuate very rapidly and extensively. In consequence of this, it is only by taking the average of such a large number of observations that the different interferences from various sources partially neutralize each other, that the comparatively coherent results shown in the Appendix have been obtained. The readings of two wind-gauges placed side by side varied with much irregularity from minute to minute, yet the total readings for any comparatively small period did not vary much, and in one particular hour the final difference between the gauge-readings was only 1 per cent. The irregularities in question are attributable to eddies, and can only be met by frequently repeated observations.

For windmill-testing, anemometers of the Robinson type are more suitable than those with a horizontal axis, which must be steered to be always parallel with the direction of the wind. In all mills there is more or less sluggishness of steering, and this affects the resulting efficiency. However suddenly the wind may veer, the Robinson gauge always sustains the full impulse, whereas a helical wind-meter will only record that component of the velocity which is parallel to its own axis. Thus the Robinson gauge integrates all the wind, so that the influence of steering defects is included in the mean result.

The various causes of discrepancy in individual observations may be briefly stated thus:—The inertia of the wind-gauge prevents small changes of velocity being registered. The direction, but not the velocity, of wind may change between two observations. The wind-gauge gives the velocity of the wind

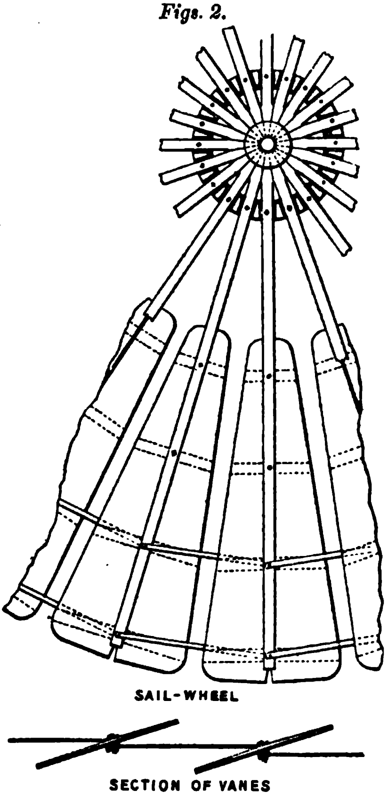
[1] "On the Power of Wind and Water." Phil. Trans. Royal Society, vol li. pt. i. 1759, p. 100; and "The Windmill as a Prime Mover." Alfred R. Wolff New York, 1885.

passing its small area, which may not be the average velocity over the whole area of the windmill. The inertia of the windmill itself causes the wind energy of several successive short intervals of observation to be distributed. With the Author's method, which is nothing less than a complete revolution of gauge or mill, any particular pair of differences in the readings may each contain an error of over half a unit, amounting to a very considerable percentage at low speeds.

Particulars of Six Types of Windmills.

In order to illustrate the methods by which these principles are applied, and to show how far the theoretical results are realised in modern practice, a description is presented of the construction of six typical examples of windmills, with a summary (contained in an Appendix) of tests which were undertaken by the Author to determine their efficiencies.

Figs. 2.



Scale, ¼ inch = 1 foot.

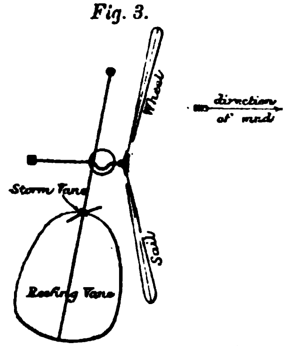
Example No. 1; 22-*foot "Toowoomba" Windmill.*—This mill was constructed by the Toowoomba Foundry and Engineering Co., Limited, for use at the Croydon Railway Station in North Queensland, and is illustrated in *Figs. 2–7.* The sail-wheel, *Figs. 2*, is 22 feet 4 inches in diameter, and the centre opening is 8 feet 2 inches in diameter; hence the effective air-stream has a sectional-area of about 340 square feet. There are 20 vanes, each on a separate arm of cedar, and each driven into sockets in the central cast-iron disk, and bolted at its edge. Each vane is made of two thin cedar boards held between the arm and four transverse battens. The two thin boards are riveted to the battens at

their outer edges only, being left free to expand with moisture at the joint between them, which is covered by the arm. The surface of the arm is sawn and dressed to an approximately helical surface, the weather-angles and pitch at six equidistant points along the radius of the vane being as follows:—

Radius in Parts.	1	2	3	4	5	6
Diameter in feet .	3′ 8″	7′ 4″	11′ 2″	14′ 10″	18′ 8″	22′ 4″
Weather angle . .	bare	40° 20′	31° 4′	24° 59′	21° 54′	18° 47′
Pitch in feet . .	arm	19·5	21·2	21·7	23·5	23·8

The figures in columns 2 and 6 are estimated, as the vanes have no appreciable width at those points. The mean pitch is 22 feet. The action of the moving reefing-vane is shown in *Figs. 3* and *4*. It is a comparatively large vane, having an area of about 80 square feet, and is mounted on a horizontal spindle in bearings on the turntable, stops being provided to limit its rotation to 90°. In working the vane is nearly horizontal, as in *Fig. 3*, and is maintained in that position by an eccentric balance-weight at the opposite end of the spindle. Another smaller "storm" vane, having an area of 6 square feet, is attached to a short arm on the spindle and stands vertically, *Figs. 3, 4, 5* and *6*, when the large vane is horizontal, and *vice versâ*. The pressure of a light wind is insufficient to overcome the balance-weight, so that the large reefing vane has its edge to the wind and is inoperative. As soon as an increase of pressure overcomes the moment of the balance-weight the reefing vane is turned at such an angle to the wind that the horizontal component of the pressure turns the sail-wheel and turntable and prevents an undue increase of speed. If the wind were uniform, this vane would probably assume an inclined position of equilibrium corresponding to each velocity of the wind, but in practice

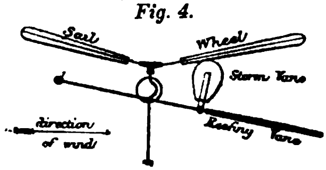
Fig. 3.



At Work.

Plan.

Fig. 4.



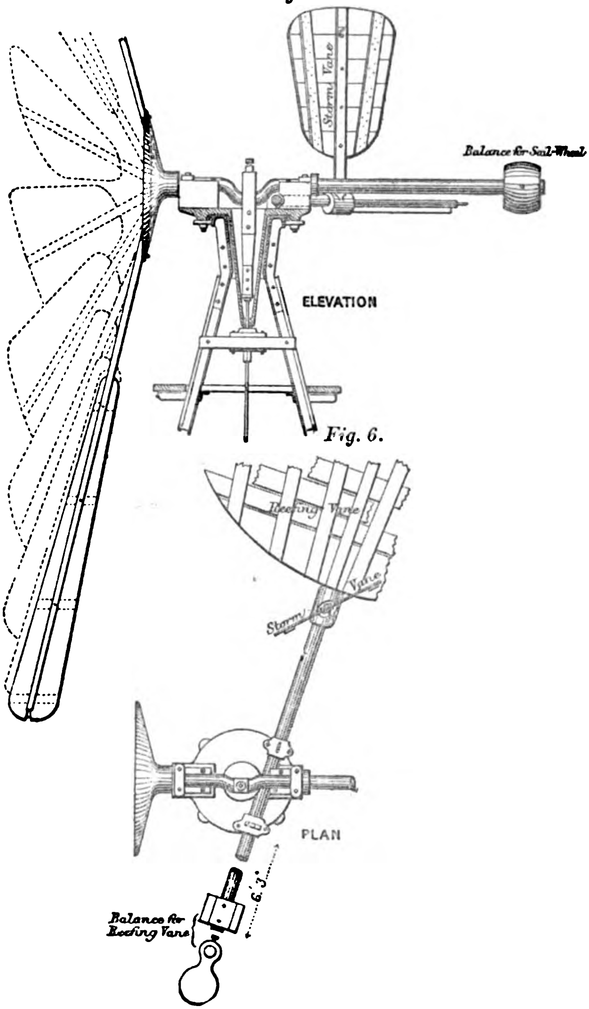
Reefed.

Plan.

the fluctuations of the wind in squally weather cause its position to change continually with a corresponding rotation of the turntable. In general, however, the moments of inertia about the horizontal

Fig. 5.

Fig. 6.

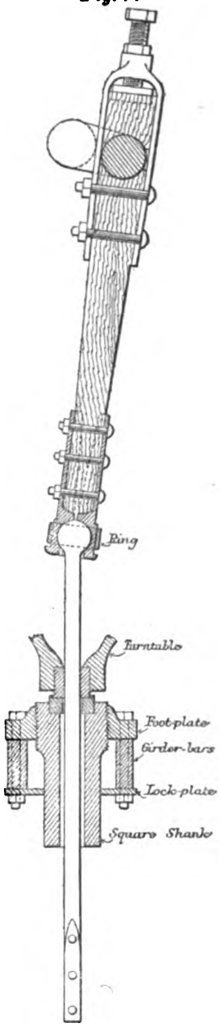


Scale, ¼ inch = 1 foot.

and vertical axes are so differently related to the acceleration that the regulating-gear will turn the table through 90° before a complete stroke of the pump can be made, and the continual

"hunting" of the governor does not cause serious fluctuations in the average speed of pumping. In heavy gales the gear may be so adjusted that in the extreme position the sail-wheel is still so far from having its axis at right-angles to the direction of the wind that it continues to work at a reduced speed. By careful design a mill may be adjusted to run, say, at 20 revolutions per minute with wind-velocity of 15 miles per hour, at 30 revolutions with one of 30 miles per hour, and at only 10 revolutions or less with a 50-mile gale. The storm vane is set at an angle of from 40° to 60° with the reefing axle, and its range of altitude may also vary between, say 30° and 120°, 60° and 150°, or 90° and 180°, and each change will affect the rate of retardation of the speed of mill as compared with the speed due to uncontrolled wind. Similar variation results from alteration of the position of the balance-weight and its moment about the reefing axle. To put the mill out of action a small loose weight is hung on the end of the storm vane to keep the reefing vane vertical, and the mill is usually so adjusted that the sail-wheel then stops. The reefing can also be effected when desired by means of a wire from the ground level, or the loose weight for stopping the mill may be permanently attached to a hinged rod, arranged so that it can be hooked on in various positions. The makers, however, discourage the alteration of these adjustments by the user. For steering, the sail-wheel is placed on the lee side of the tower, and is made conical, in order to clear the tower without the necessity of an inclined or overhanging axle, and to enable the broad ends of the vanes to be placed further to leeward with the object of obtaining a greater turning moment. With a freely moving turntable the steering is satisfactory. The main shaft is 3 inches in diameter with a bent crank giving a stroke of $6\frac{3}{4}$ inches to a 5-inch siphon pump, with a capacity of 0·478 gallon per

Fig. 7.



Scale, 1 inch = 1 foot.

DETAILS OF CONNECTING-ROD AND ADJUSTABLE FOOTSTEP.

stroke. The pump load-factors are 30·36 foot-lbs. and 121·9 foot-lbs. for lifts of 25 and 100 feet respectively. The movable part is supported at the lower end on a steel footstep of small diameter, fitted with a vertical screw adjustment, *Fig. 7.* The upper end is steadied by four rollers attached to the upper table. A flange on the lower casting overhangs the rollers and prevents the table from being lifted by wind in a vertical direction.

The mill was tested while temporarily erected over an artesian well in trap rock. The load was obtained by pumping into an air-vessel provided with a loaded safety-valve and pressure-gauge, and the tests were carried out at pressures of about 10 lbs. and 40 lbs. per square inch. The "F" wind-gauge was erected on a separate tower about 50 feet to windward of the mill, but subsequent experience has shown that this was too great a distance at which to measure with accuracy the wind passing the mill. The speed of the pumps was recorded by a 6-figure reciprocating counter, and the water delivered was measured in a tank and found to agree with that computed from the capacity and speed of the pump. At first the average speeds of wind-gauge and mill were read at $\frac{1}{4}$ hour and longer intervals, but subsequently it was found necessary to take observations at intervals of from 1 to $\frac{1}{2}$ a minute. For every velocity of wind it was necessary to determine the corresponding average number of revolutions of the mill for the unit of time.

Let R denote the number of revolutions of the mill per minute, and V the velocity of the wind. Then from the measured quantity of water lifted by the pump per minute, the total quantity of water lifted in gallons per hour is

$$R \times 60 \text{ minutes} \times 0{\cdot}478 \text{ gallon} = 28{\cdot}68\ R,$$

the total HP. is

$$\frac{R \times 10 \text{ lbs.} \times \text{lift in feet}}{33{,}000} = \begin{cases} \text{for } 25\text{-feet lift, } 0{\cdot}003621\ R, \\ \text{for } 100 \quad ,, \quad , 0{\cdot}014485\ R, \end{cases}$$

the HP. for 100 square feet of gross area of sail-wheel is

$$\frac{\text{Total HP.} \times 100 \text{ square feet}}{392 \text{ square feet}} = \begin{cases} \text{for } 25\text{-feet lift, } 0{\cdot}000924\ R, \\ \text{for } 100 \quad ,, \quad , 0{\cdot}003695\ R, \end{cases}$$

and the total (available) HP. in the wind for gross area

(coefficient from Table I) × area.

The net combined efficiency of the mill and pump is obtained

by dividing the total HP. developed by the total HP. in the wind for gross area.

The actual efficiency of the sails will be greater than this in the combined ratio of the gross area of sail-wheel to the net area covered by the vanes and of the counter-efficiency of the pump. Thus, if the friction of the pump and journals absorbs 15 per cent., the efficiency of the vanes of this mill will be obtained by multiplying the net efficiency by the coefficient

$$\frac{\text{gross area}}{\text{net area}} \times \frac{100}{85} = \frac{392}{340} \times \frac{100}{85} = 1 \cdot 357.$$

The ratio

$$\frac{\text{R} \times \text{pitch in feet} \times 60 \text{ minutes}}{5{,}280 \times \text{V}} = \frac{\text{R}}{\text{V}} \times (\text{a coefficient})$$

is, for the outer rim of this sail-wheel, 0·270
,, inner ,, ,, 0·234.

In spite of the paucity of data, the results obtained with this mill show conclusively that the most important element in the efficiency is the "pump-load factor," and that with a light load the speed of a mill will by no means increase sufficiently to equalize the duty.

Example No. 2; 12-*foot* "*Stover*" *Windmill.*—This mill was constructed at Freeport, Ill., U.S.A., and is erected at Charters Towers to pump water from a well to a tank which supplies a garden and stables. Its construction is shown in *Figs. 8, 9* and *10*. The sail-wheel is of the solid-wheel pattern, with seven sectors having sixteen vanes in each. The vanes are of $\frac{3}{8}$-inch pine, tapering from $3\frac{3}{4}$ inches to $1\frac{1}{2}$ inch in width. The external and internal diameters are 11 feet 6 inches and 4 feet 6 inches respectively, giving a gross area of 104 square feet and a net vane surface of 88 square feet. The vanes, *Fig. 10*, are notched to curved rails, which are bolted to the seven radial arms. The vanes are set without twist, with a constant weather averaging 43°, so that the pitch varies between about 13·2 at the inner diameter and about 33·7 feet at the outer diameter. The main axle is over the centre of the turntable, and there is no automatic regulation. The rudder vane is hinged as nearly as possible over the centre of the turntable, and is held square to the wheel by a loaded wooden lever, moving in a plane slightly inclined to the vertical and connected to the rudder arm by a link with a universal joint. By means of a chain and control wire, this lever can be raised and fixed at any height, so that the

mill may be completely "reefed" and stopped, or regulated to go slowly in gales and storms. A brake-drum, 8 inches in diameter

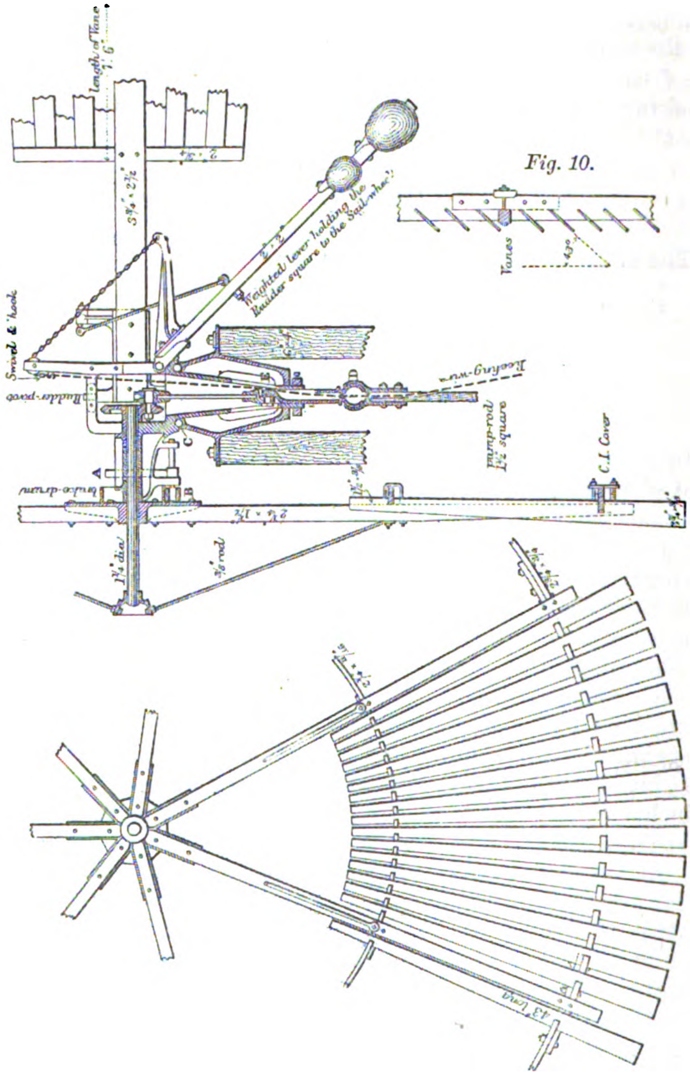


Fig. 9.

Fig. 10.

Fig. 8.

Scale, $\frac{1}{24}$ inch = 1 foot.

and 2 inches wide, is formed on the hub of the sail-wheel. When the rudder is reefed, a projection from the hinge-casting presses against the lever A, *Fig. 9*, and presses the shoe B against the

brake rim. After four years' work, without attention, this brake had become ineffective, owing to backlash, yet the wheel stopped satisfactorily when reefed, showing that in this particular case the brake was not an essential adjunct. The crank-disk has three holes for the crank-pin; the greatest stroke, which was that always used, being 4 inches. The turntable is carried on a set of cast-iron balls, each 1 inch in diameter, arranged in a circular groove, about 8½ inches in diameter, shown at C, *Fig. 9*. This roller path is protected from rain by the overhanging casting, but is not lubricated, and after four years' use is in perfect order. The swivel-joint below the turntable is a hollow sphere of cast-iron, 3 inches in diameter, held between two cast-iron clips bolted to the top of the wooden pump-rod. The pump works drowned and has a brass 3-inch cylinder and piston. The tank is situated at a distance of 482 feet from the mill, but the friction of the 1½-inch main pipe was, during the experiments, quite inappreciable. During the tests the average lift was 61·2 feet to the tank, and 21·2 feet to a side-cock at low-level.

The tests were made between November 5th and December 27th, 1891. After short preliminary trials, observations were made every ten seconds. The gauge was fixed on an arm projecting as far as possible to windward, and an ordinary watch with seconds hand was placed close above the units dial of the gauge. A counter, driven by a wire from the pump-rod, was also fixed close to the watch. The observer stood on the ladder of the mill, with his eyes at about the level of the lower edge of the sail-wheel and to windward of the tower. During the set of tests in question no period of ten seconds elapsed in which the gauge made less than 5 revolutions. Usually the mill stopped whenever its speed fell below seven turns per ten seconds. The results show that the average mill-speed is a constantly increasing function of the wind-velocity. The maximum wind-velocities were too high for the pump, which at 60 revolutions per minute shook the tower violently, and at such speeds in ordinary work the mill should have been partially reefed.

Example No. 3; 16-*foot* "*Perkins*" *Windmill*.—This mill was constructed at Mishawaka, Ind., U.S.A., and is employed for the irrigation of a garden and orchard, and for domestic purposes. The sail-wheel has eight sectors with twenty vanes in each. The external and internal diameters are 16 and 6 feet respectively, giving a gross area of 201 square feet, and a net vane area of 173 square feet. The vanes are of pine, 4 inches by ½ inch, tapering to 1½ inch by ½ inch, and are supported on three rings of

bent wood, each in eight segments. The scantlings of the segments are respectively $3\frac{1}{2}$ inches by $\frac{3}{4}$ inch, $2\frac{3}{4}$ inches by $\frac{3}{4}$ inch, and 2 inches by $\frac{5}{8}$ inch, and they are attached to the arms by U bolts; but the segments are not themselves "fished" (as in *Figs. 9* and *10*), and consequently loosen somewhat under the strains. The vanes have no twist, and have an approximately constant weather, averaging 36°, while the pitch varies between 13·7 and 36·5 feet. The main axle is 2 inches in diameter, and is cranked, with soft-metal bearings at each end. The connections to the pump-rod are such that the up-stroke occupies about 197°, and the down-stroke 163°. In a single-acting pump this would be advantageous, but as in the case in question the pump is double-acting, it would have been better to reverse the direction of motion, with the object of equalizing the delivery. The diameter of the piston is 3 inches, and that of the pump-rod in the stuffing-box $\frac{5}{8}$ inch, the stroke being $5\frac{3}{8}$ inches. Owing to the relatively small area of the valves and water-passages, the pump does not work satisfactorily at a greater speed than 30 strokes per minute, and a wind velocity of somewhat more than 10 miles per hour. The crank is balanced. The bearings on the turntable are close together, and the turntable is mounted on a wrought-iron tube, $3\frac{1}{2}$ inches in external diameter and about 3 feet long. The cast-iron frame of the upper turntable is connected to one end of this, and the whole weight is supported by means of a collar on a cast-iron plate on the top of the four wooden tower posts. The lower end of the tube is held in another collar, adjustable by four bolts. The lubrication of the main collar is defective, and a row of ball-bearings would be preferable to the existing arrangement. The rudder vane is 16 feet long, and between 2 and 5 feet wide, and it extends 20 feet, yet the steering is very sluggish. The steering rudder is also intended to act as an automatic regulator. It is hinged to the turntable by an axis inclined to the vertical, the angle being adjustable by screws, and as it moves round towards the wheel its centre of gravity rises. The sail-wheel is placed 7 inches from the turntable axis, and in high gales it is intended that the pressure of the wind on the sail-wheel shall overbalance the weight of the rudder and reef the mill. So far, however, there has never been a wind of sufficient strength to do this, and reefing is in practice effected by a hand-winch.

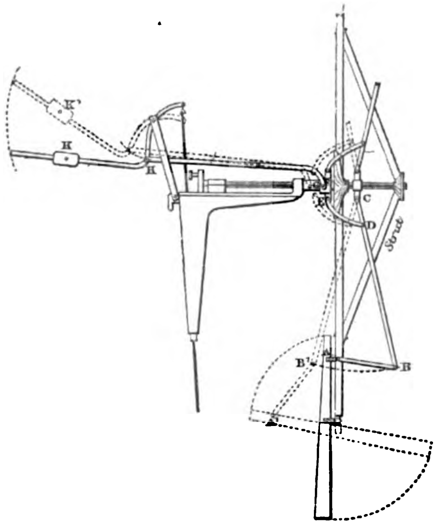
Special tests were made to ascertain approximately the diminution of speeds when the rudder was held respectively at about 70°, 45°, and parallel to the sail-wheel. During these trials the wind-gauge was erected on the adjoining tank-tower,

between 10 and 12 feet to one side of the centre of the stream of wind passing the mill. The speed counter was arranged to register half strokes, both on account of the double-acting pump and of the comparatively low speed of the mill. As in previous experiments, readings were taken at 10-second intervals. When the mill is running unloaded, there was a little negative wind-pressure at the outer circumference of the sail-wheel with velocities of wind above 7 miles per hour; but when loaded the speed of the mill was so reduced that the wind-incidence was always positive.

Example No. 4; 14-foot "Althouse" Windmill.—This mill is erected at a residence at Charters Towers, and supplies the premises. The sail-wheel has eight folding sectors of thirteen vanes each. Each vane is 48 inches long, and $\frac{1}{4}$ inch thick, and tapers from 4 inches to $1\frac{1}{2}$ inch. The gross area of the sail-wheel is 157 square feet, and that of the vane ring 141 square feet. The vanes are mounted without twist in the ordinary manner on two bars, one of which ($2\frac{3}{4}$ inches by $\frac{7}{8}$ inch) carries iron sockets which swivel on the polygonal tie-rods of the main wheel, while the other ($2\frac{1}{4}$ inches by $\frac{7}{8}$ inch) ties the small ends together, and is held in position by the links of the regulating-gear. The "weather" averaged 30°, but many of the unsupported ends of the vanes were warped through several degrees. The pitch of the wheel, when flat, varies between 8·5 feet at 4·5 feet diameter and 25·8 feet at the outer circumference. The centre of figure of the whole vane-sector is about $4\frac{1}{2}$ inches outside the axis on which the vane is pivoted, so that the wind-pressure tends to open the vanes even when the wheel is at rest. The whole sector is also on the tower side of the plane in which the polygon of axes lies, so that the centrifugal force, as well as the wind-pressure, tends to open the vanes when in motion, and both increase respectively with the speed of rotation and with the velocity of the wind. The vanes are held against light winds by a balance-weight of about 15 lbs. acting through the system of linkwork outlined in *Fig. 11.* This is connected to the vane-sector at a radius of $15\frac{1}{2}$ inches from its axis, and the point of attachment to the first lever at B moves through about $21\frac{1}{2}$ inches. This is reduced in the ratio of 7·43 by the lever BC, and communicated through links DE to a bush F sliding outside the fixed bearing G, which is rigidly attached to the turn-table. The ring collar on F is connected by the link FH to the short arm of the weighted lever. In consequence of defective design, however, this gear acts very unsatisfactorily. It was so sluggish and irresponsive to considerable wind variation, that no

attempt was made to analyse experimentally its action, and the balance-weight was never moved from its ordinary position at 2 feet radius. The main axle is carried in two metallic bearings on a cast-iron bracket projecting 30 inches from the turntable axis, to allow the sectors to fold clear of the centre-posts. The axle is prolonged to leeward of the wheel, and to its end is attached a socket supporting the feet of struts which brace the arms of the wheel together. The arm opposite the crank carries a weight of

Fig. 11.



Scale, ¼ inch = 1 foot.

6¼ lbs. at a radius of 56 inches. The construction of the turntable is the same as that of the next example, shown in *Fig. 13*.

The pump is a double-acting Tangye pump with separate valve-boxes in a cast-iron body, having a 3-inch brass cylinder-lining. It is fixed a few feet above the mean water-level in the well, and gives considerable trouble in priming when air leaks in after stoppages. The actual stroke is 5 inches, although the pump is designed for a maximum stroke of 8⅞ inches. The average lift during the trials was 66·3 feet, the tank being on the mill tower directly above the well. Owing to defective valves, the delivery of water was less than that due to the volume swept through by the piston. In calculating the duty the theoretical delivery was used, the reaction on the sail-wheel being the same as if the full volume of water had been delivered. The maximum speed at which the mill was driven was about 40 revolutions per

minute with a wind-velocity of 15 miles per hour, and at this speed the pump showed signs of overwork.

Example No. 5; 10-foot "Althouse" Windmill.—This mill is also erected at a residence at Charters Towers. The sail-wheel has six folding sectors of fourteen vanes each, *Fig. 12.* The vanes are of pine, 38 inches long by $\frac{1}{4}$ inch thick, and taper from $3\frac{3}{4}$ inches to $1\frac{1}{2}$ inch in width. They have no twist, and are mounted in the usual manner. The average weather was found to be 28°, but many of the free ends of the vanes were warped 4° or 5°. The pitch of the vanes for the average weather varied between 6·4 feet at 3 feet 10 inches diameter and 17 feet at 10 feet 2 inches diameter at the outer ends of the vanes. The centre of figure of the sector is almost exactly opposite the axis of suspension when the wheel is flat, so that in light winds the wind-pressure is practically balanced on each sector. As the wheel opens under the regulating action the wind gains a slight leverage tending to open the wheel, but its amount is insignificant in this particular mill. The regulation is almost entirely due to the centrifugal action of the weight of the sector, the centre of gravity of which is at a rather smaller radius from the main shaft than its axis, and moves outwards as the wheel opens. The governing gear is connected at C, *Fig. 13*, to a flat iron rod, which is bolted by cast-iron lugs A B to the frame bars of the sector. The wheel opening under centrifugal action pulls at the rods C D, and moves the bush D, which slides on the main shaft towards the tower. The bush D is rigidly connected to another at E by two $\frac{3}{8}$-inch rods sliding through holes in the hub of the sail-wheel. The bush E has a loose collar linked to the loaded lever F G. The position of the weight G, of 14 lbs., can be varied between $13\frac{1}{2}$ and 34 inches radius, causing a moment tending to hold the wheel flat of between 16 and 40 foot-lbs. The main axle is carried in a metallic bearing at the inner end next the crank, and at the outer end in a wooden bearing bolted to the turntable arm at H. The latter bearing is not in contact with the shaft itself, but supports a prolongation of the boss of the sail-wheel. There are no ties between the axle and the main arms of the sail-wheel. The pump-rod is balanced by a cast-iron weight of 14 lbs. attached to the arm of the sail-wheel opposite the crank, at a radius of 33 inches. The horizontal thrust on the upper bearing of the turntable is received by a pair of rollers fixed to a small loose carriage, which can be adjusted when required by the set-screw K. As, however, these rollers are generally less than 2 inches in diameter and on $\frac{1}{2}$-inch pins, they very soon set

fast and become useless. The pump has a brass cylinder of 3 inches diameter with cast-iron covers, and works submerged.

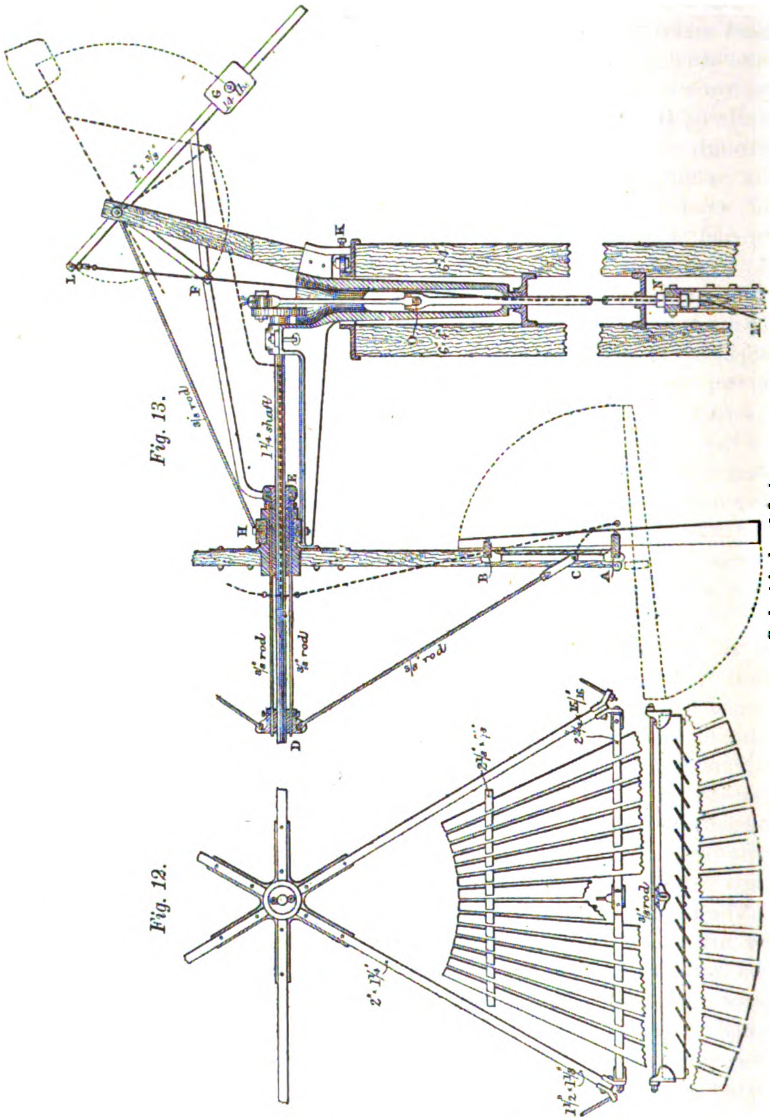


Fig. 13.

Fig. 12.

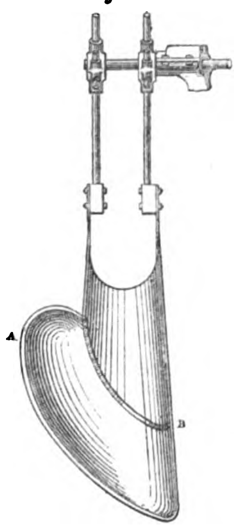
Scale, ¼ inch = 1 foot.

10-FOOT RUDDERLESS FOLDING MILL.

The tank is 24 feet above the ground, and the total lift during the trials averaged 38·7 feet.

Example No. 6; 10-*foot "Carlyle" Windmill.*—This mill was manufactured in America, and pumps water for domestic and garden supply at a residence near Brisbane. It has seven vanes made of sheet metal with stiffened edges, the vanes being bolted to tubular iron arms, and trussed by light iron rods. The main portion of the vane is spoon-shaped, *Fig. 14*, with its weather so arranged as to direct the departing stream of air into a spout-like extension, through which it flows after the manner of a reaction turbine. The spout is so shaped that the reaction in it opposes the effort of the wind upon the spoon-shaped part of the vane, the difference of the efforts constituting the effective force. In practice the effort of the wind upon the spoon overcomes that upon the spout. The angles of weather at the leading and delivery edges, A and B, are respectively (approximately) 50° and 14°, the corresponding pitches being 22·4 feet and 7·2 feet. The turntable is generally similar to that of Example No. 3, and the crank is placed on one side of the vertical axis, and is connected with the pump-rod by similar gearing. The rudder is arranged to reef the mill in storms; but instead of its weight acting through an inclined hinge, as in Example No. 3, the rudder is attached with a Hooke joint without rotation, and the weight is supported on a guy-chain from the top part of the turntable frame, where it wraps round an adjustable cam, thus causing the centre of gravity of the rudder to rise as it folds towards the wheel. The eccentricity of the sail-wheel axis is 5½ inches, and the mill reefs itself in very high winds.

Fig. 14.



The pump is a 3-inch "Siphon" pump with a 4-inch stroke, and the lift during the trial was 30·7 feet. The rods are balanced by a counter-weight of about 17 lbs. The efficiency given in the Appendix is the result of only two trials which were made during a light wind on the 26th January, 1892. The efficiency of the mill and pump together is of the average amount, and its speed of revolution is lower than that of other mill-wheels of the same diameter.

The Paper is accompanied by 19 sheets of drawings, from a selection of which the *Figs.* in the text have been prepared.

[APPENDIX.

APPEN

PARTICULARS OF WIND MILLS

	1	
Description of mill	Toowoomba conical sail-wheel with reefing-vane	
Diameter of sail-wheel at outer ends of vanes . . feet	22·33	
„ „ inner „ „ . „	8·33	
Gross area of sail-wheel . . . . square feet	392	
Weather angle at outer ends of vanes	18° 47′	
„ „ inner „ „	38° 20′	
Pitch of vanes at their outer ends . . . . . feet	23·80	
„ „ „ inner „ . . . . . . „	20·60	
Ratio of mean pitch to outer diameter . . . „	0·99	
Mean velocity of wind at starting and stopping without pump-load . . . . miles per hour	..	
Diameter and stroke of pump . . . . inches	5 × 6⅝	
Average head of water during tests . . . . feet	25	100
Pump load-factor, per gross area	30·36	121·95
„ „ „ net „	35·00	140·60
Mean velocity of starting under pump-load, revolutions per minute	3·00	5·00
At Maximum Efficiency.		
Velocity of wind at maximum efficiency miles per hour	4·300	7·000
„ mill „ „ revolutions per minute	5·000	6·800
Actual HP.	0·018	0·098
HP. per 100 square feet of gross area	0·005	0·025
Maximum net efficiency . . . . per cent.	10·300	12·600
Circumferential velocity of tips of vanes at maximum efficiency . . . . miles per hour	3·980	5·420
Ratio of velocity of tips of vanes to speed of wind	0·926	0·774
Helical slip at outer ends of vanes . . miles per hour	0·280	0·260
„ „ inner „ „ . . . . „ „	0·240	0·230
In 100 average Hours in Calm Locality.		
Average quantity of water lifted . . gallons per hour	495·000	306·000
„ continuous HP. developed per 100 square feet.	0·016	0·039
„ „ gross HP. „ „ . . .	0·063	0·153
„ net efficiency . . . . per cent.	1·500	3·800
In 100 average Hours in Windy Locality.		
Average quantity of water lifted . . gallons per hour	816·000	629·000
„ continuous HP. developed per 100 square feet.	0·026	0·081
„ „ gross HP. „ „ „	0·102	0·317
„ net efficiency . . . . per cent.	0·360	1·110

DIX.

AND RESULTS OF TESTS.

2		3	4	5	6
Stover Solid sail-wheel with rudder, hand control. . .		Perkins Solid wheel, automatic rudder	Althouse Folding sail-wheel, rudderless	Althouse Folding sail-wheel, rudderless	Carlyle Special type, automatic rudder
11·5		16·0	14·16	10·16	9·83
4·5		6·0	4·5	3·83	4·16
104		201	157	81	80
43°		36°	30°	28°	50°
”		”	”	”	14°
33·68		36·51	25·69	16·98	22·40
13·12		13·69	8·16	6·40	7·20
2·03		1·57	1·20	1·15	1·45
3·20		2·50	3·00	2·60	3·00
3×4		3 × 10¾	3 × 10	3 × 4⅝	3 × 4
29·20	61·20	39	66·30	38·70	30·70
28·63	60·01	53·16	107·68	55·89	39·10
33·84	70·93	61·77	119·90	65·60	46·73
4·00	4·80	4·00	5·00	6·00	4·00
5·800	6·500	6·000	7·000	8·500	6·000
13·000	13·300	7·500	12·600	20·500	12·500
0·011	0·025	0·024	0·065	0·028	0·012
0·011	0·024	0·012	0·041	0·035	0·015
8·700	14·400	8·900	19·300	9·000	10·400
5·340	5·350	3·880	6·370	7·430	4·380
0·921	0·823	0·647	0·910	0·874	0·730
0·860	0·770	0·190	0·510	0·470	0·530
0·340	0·300	0·120	0·170	0·180	0·170
153·000	135·000	259·000	267·000	115·000	145·000
0·022	0·040	0·025	0·057	0·028	0·028
0·023	0·042	0·050	0·089	0·023	0·022
2·100	3·900	2·500	5·500	2·700	2·700
287·000	271·000	525·000	540·000	237·000	270·000
0·041	0·080	0·051	0·115	0·057	0·052
0·043	0·083	0·102	0·180	0·046	0·042
0·280	1·110	0·710	1·590	0·780	0·720

(*Paper No. 2848.*)

"Steam Tramways in Italy."

By P. Amoretti.

(Translated and abstracted by P. W. Britton, Assoc. M. Inst. C.E.)

Preliminary.—During the last fifteen years, and especially in the decade from 1880 to 1890, a remarkable length of steam tramways has been constructed in Italy, so that a perfect network of lines is now in existence in the valley of the Po, as well as round important centres in other parts of the peninsula.

The first tram-lines on which trains were worked by steam power were originally constructed for horse-traction, the steam motors being introduced partly for economical reasons, partly to increase the carrying capacity. The system soon attained to such a development that, with the increasing length of various lines, and their great proportion of goods as compared with passenger traffic, they might almost be considered as secondary railways. There is, however, one fundamental distinction between steam tramways and light railways, and that is that the former are laid on ordinary high-roads, without any fencing off from the open carriage-way, the speed of the trains being proportionately limited.

Except in the case of Crown domains or national property the Government does not intervene in respect of ordinary horse tram-lines; but, in regard to employment of mechanical traction, the conditions of working consonant with public safety are strictly defined by statute. These conditions refer chiefly to the type of locomotive, composition and length of trains, and speed. Up to the present time there is no law governing the details of construction, the only technical restrictions being in respect of the rolling stock and the working arrangements.

At the end of the year 1890 the length of steam tramways constructed in Italy was stated in the official returns as 1,575 miles, and about 300 miles have been constructed since that time (Plate 9). Owing partly to the commercial crisis through which Italy has recently been passing, and partly to the unsatisfactory results of

the working of many of the lines, the rate of construction has much diminished since the close of 1890.

The existing network originated in the lines radiating from large centres, such as Turin and Milan: lines, originally terminating in the immediate suburbs, being extended to outlying points, until they met or crossed lines from other centres. At first these various lines were worked independently of each other, and their functions were limited to local traffic; but as the system extended, joint working arrangements were made, and through traffic was provided for between the several lines and, where practicable, over the railway systems. This development was, of course, impossible where varying gauges had been adopted.

The greatest extension of through, or cumulative, working is in Lombardy, and an important factor in the system is the circular line at Milan, connecting all the lines which converge on that city. Goods can be conveyed without transfer for considerably over 100 miles, as from the Province of Pavia to Mantua or Brescia. Other isolated lines play an important part in the economical development of the country's resources, as, for instance, in the smaller valleys of the Alps and Apennines, where the extent of traffic would never permit of the construction of a railway. In many cases the railway wagons or carriages can be worked over the tramway system; and this can often be seen on the tramway lines radiating from Pisa.

About thirty-six tramway companies, working 1,365 miles, have since 1886 combined to form the Italian Tramway Association, by which a common basis of working is established, and all administrative matters discussed and regulated.

Construction of the Lines.

In the majority of cases the standard Italian railway gauge, 4 feet 8½ inches, has been adopted. In Piedmont there are instances of 3 feet 7¼ inches gauge, and others of 2 feet 11½ inches. A few are laid to the narrow gauge of 2 feet 5½ inches. That so fundamental a mistake as the adoption of different gauges was ever made can be explained only by the entire absence of any conception of the ultimate extent to which the several undertakings would develop and coalesce. Where there are physical obstacles to any future connection with other systems the adoption of a narrow gauge has enabled most satisfactory financial results to be obtained.

It is a rigidly enforced condition that the rail-level shall exactly coincide with the road-surface, so as to offer no impediment to ordinary vehicles. It was also originally required that the space between the rails should be metalled in a precisely similar manner to the rest of the roadway; but in many cases the metalling is allowed to be rough dressed, so that while vehicles can traverse the space without impediment, there is no inducement for them to remain upon the line.

The width of ordinary roads is from 26 feet to 29 feet 6 inches, and the position of the line is fixed as in *Fig. 1*. The width of 26 feet is considered as the normal minimum, but in exceptional cases it has been allowed at as little as 20 feet. Where the width

Fig. 1.

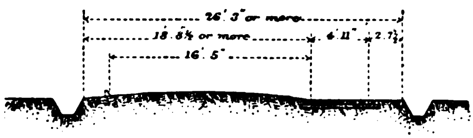
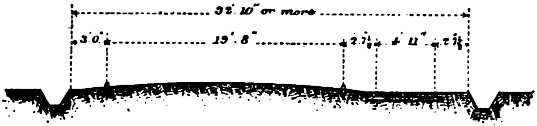
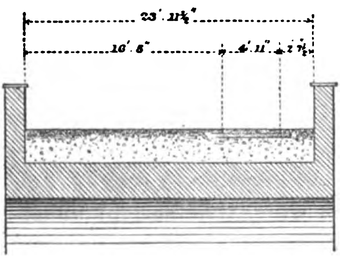


Fig. 2.



of the roadway is 32 feet 10 inches or more the line is practically separated from the roadway by a series of spurstones (*Fig. 2*), these being omitted in the narrower section (*Fig. 1*). The separation is naturally conducive to greater immunity from accidents. On bridges the minimum distance from the rail to the nearest parapet is 2 feet 7½ inches and 16 feet 5 inches on the other side, so that the minimum section is as shown in *Fig. 3*. In some cases, on narrower bridges, iron parapets have been substituted for masonry or brick, or the footpath is carried on cantilevers.

Fig. 3.



In traversing streets the line is laid, where practicable, in the centre of the roadway; but in narrower places it is necessary to leave the maximum free width

on one side, and the normal minimum distance from the rail to the nearest wall of the house is 3 feet 11 inches (*Fig. 4*).

The steel rails used are exclusively of the Vignoles type, fixed direct to the sleepers on straight lengths and on chairs when in curve. In towns guard-rails are used to facilitate packing the metalling, the width for the flange of wheel being about 1⅜ inch.

Fig. 4.

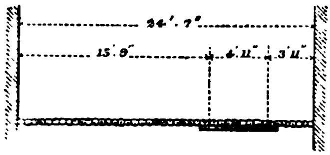
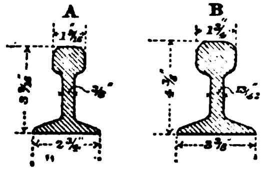


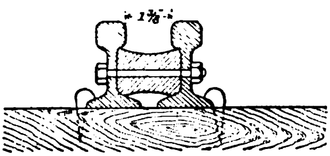
Fig. 5.



The rail generally adopted (*Fig. 5*, Type A) weighs 36 lbs. per lineal yard; but where the engines used weigh over 12 tons, or the traffic is very heavy, the section Type B, weighing 42 lbs. per lineal yard, is used. The sleepers are always of oak, which abounds in Italy, the dimensions for standard gauge lines averaging 4¼ inches × 7 inches × 7 feet 3 inches long.

In laying the line the road metalling is broken up, and a layer of screened gravel from 4 to 6 inches in thickness is spread, upon which the sleepers are laid and packed up in ballast similar to the road-surface. The sleepers are spaced at from 2 feet 7½ inches to 3 feet, centre to centre, and at rail-joints from 1 foot 4 inches to 1 foot 8 inches. The rails are secured to the sleepers with spikes, the use of coach-screws having shown very unfavourable results.

Fig. 6.



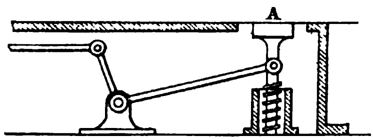
Guard-rails (*Fig. 6*) are used in nearly all cases of curves of less than 2½ chains (55 yards) radius. With a few unimportant exceptions, no exclusively metallic permanent way has up to the present been adopted in Italy, on account of the low price of timber as compared with iron or steel.

The points vary little from those on railways. They are generally worked by levers with counterweights; but in towns, where such an arrangement could not be adopted in the open

street, the lever is contained in a cast-iron box flush with the ground-level (*Fig. 7*), and is fitted with a foot-plate and counter-spring. The plate is thus kept in its normal position, flush with the opening at the ground-level; but when pressed downwards by the foot, it operates the lever and moves the points.

Passing now to examine the planimetric and altimetric conditions, it will speedily be observed that, in regard to curves and gradients, the one general guiding principle that has been followed appears to be simply to construct the line at all hazards. The articles of concession usually state that no curves shall have a radius less than 55 yards; but the exceptions granted have been so numerous that it may be said that no practical limit is recognised. For instance, in the neighbourhood of Turin and Milan numerous curves occur with radii of 44 and 33 yards; and in more outlying localities radii of between 20 and 40 yards are far more common than easier curves. The rigid wheel-base being, on the average, only 5 feet 3 inches from axle to axle, both engines and cars pass readily over these curves, the gauge being slightly eased.

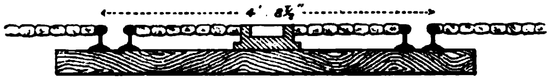
Fig. 7.



It is the same with the gradients as with the curves; in any case the limiting rate of inclination can, in view of the system of simple adhesive traction, only be considered as excessive. Thus, on the line from Rome to Tivoli, on the Road near Villa Adriana, the gradient is 1 in $17\frac{1}{2}$. In Genoa, there is an electric line on the trolley system from the town to the cemetery, of which the gradient is 1 in 15. On one line in the province of Alessandria, on the hill of San Salvatore, the gradient is 1 in $16\frac{2}{3}$, the same inclination occurring also on the line to Chianti, near Florence. In the neighbourhood of Turin, on the line to Brusasco there are several inclines of 1 in 20. In all these, the locomotives are only four-wheeled, and weigh, in full working order, not more than 16 tons. Of course, with such steep gradients, the utility of the line is much restricted, especially in regard to the conveyance of goods, or general freight; the limit of weight of a train, including the engine, being 35 tons, the margin is sufficient for passenger service only. In most cases (even when the cost of construction has been increased) the lines have been laid out so as not to have any

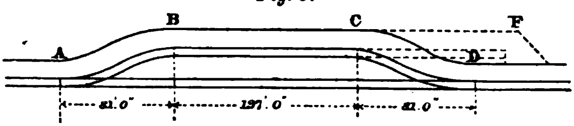
steeper gradient than 1 in 25. In one case only, at Naples (*Fig. 8*), is the ordinary adhesive traction supplemented by a central rack. This, like the rails, is flush with the road-surface, the engine being fitted with the usual arrangement for gripping or releasing the rack.

Fig. 8.



With but few exceptions—these being trunk routes, common to several lines—the steam tramways of Italy are all single lines, with passing places at such distances as are required by the extent of the traffic. These passing places (*Fig. 9*) are usually placed on the side away from the road, if an extra strip of land can be acquired for the purpose. The length of the second line varies according to requirement, the dimensions frequently adopted being 359 feet between the points, giving 197 feet clear passing length. The length of the trains is limited to about 130 feet, but it may happen that cars have to be coupled or uncoupled and shunted. Where such shunting is of ordinary occurrence, or cars have to be left for loading or unloading, it is desirable to construct a short dead-end siding. So far as possible, these passing places are provided on public ground or at regular

Fig. 9.

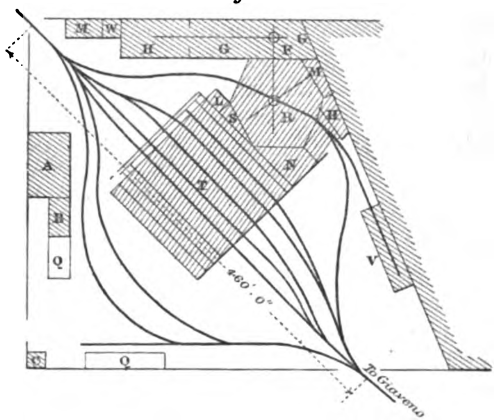


stations, as the Tramway Companies have no compulsory powers for the purchase of land. The stations are perfectly simple in arrangement, the utmost accommodation being a booking-office and waiting-room, generally in a house adjoining the stopping-places. If there are no houses close by, a small wooden building is erected. At unimportant points there is no building, but simply a sign-board with the inscription: STOPPING PLACE, to indicate where passengers may await the passing of the train. The terminal stations are, of course, on a larger, though still on the simplest possible, scale.

The Turin station of the Turin, Orbassano, and Giaveno line is shown in *Fig. 10*. It is technically a terminal station, though the starting-point is nearly 1,000 yards further towards the centre of the city, where it was impracticable to acquire the necessary ground.

The letters on the plan indicate: A, booking-office; B, goods warehouse; Q, goods sheds; T, carriage shed; R, engine shed; and M, V, F, G, and H, repairing shops, forge, and stores. *Fig. 11*

Fig. 10.



is an example of a small wayside goods-station at Piossasco. The passenger building (booking-office and waiting-room) is shown by S U; M, Q, and R being respectively warehouse, goods shed, and carriage lock-up.

Fig. 11.

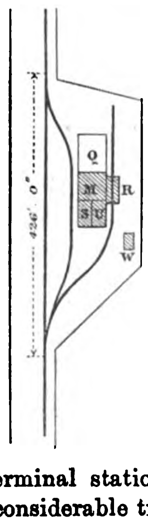
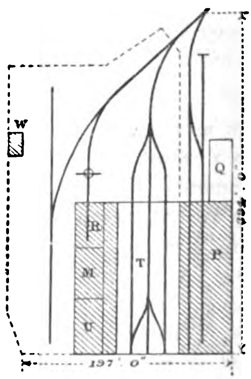


Fig. 12.

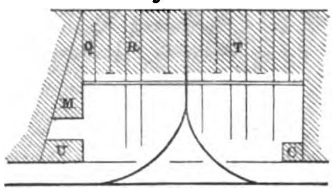


The terminal station of Giaveno, where there is, in a small space, a considerable traffic of both passengers and goods, is shown in *Fig. 12.* The references are: U, booking-office and waiting-

room; R, engine-shed; T, roof over arrival and departure lines, forming carriage-shed; P, goods warehouse; and Q, open goods shed.

In these types of station, all shunting work can be done by the engines. Another type (necessitated by greatly restricted space, but occasioning some inconvenience in working) is the station of Monza, shown in *Fig. 13*, where connection between the different buildings is effected by a transverse travelling platform. The references are: U, booking-office; M, O, workshop and stores; R, engine shed; T, carriage shed.

Fig. 13.



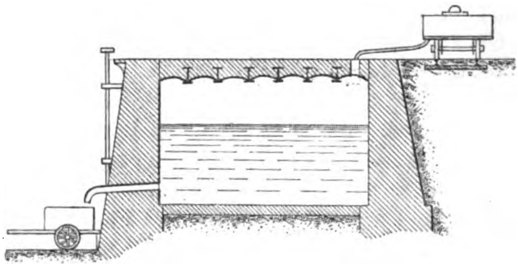
If regular stations are of infrequent occurrence on the steam tram-lines, the connections with private sidings are, on the other hand, very numerous. By the fact of their construction on the high roads, the lines afford direct communication with farms, fruit-gardens, dairies, mills, factories, ironworks, brickworks, limekilns, quarries, and mines, in a manner unattainable on such a general scale by ordinary railways. The trucks are loaded direct, and run without any transfer straight to their point of distribution, while the materials required from the city by the works and factories are similarly brought to them with a minimum of expense in handling.

The development of this important branch of traffic resources has induced the various companies to do their utmost to facilitate loading and unloading processes. Thus, for instance, for the conveyance of bricks and tiles from the extensive works at Beinasco to Turin, the trucks are simple platforms, carrying three or four open cages in which the bricks or tiles are stacked straight from the field. On arrival at Turin, the cages are slung off by a crane on to carts, and thus conveyed to their destination without one intermediate process of handling, thus avoiding cumulative charges and attendant percentage of damage. Another special class of work is the conveyance of fæcal matter from Milan to outlying sewage farms. The matter is removed in the first place in iron tanks on ordinary carts to the tramway station, where the tanks are slung by the crane on to platform trucks. At their destination, the tanks are either emptied direct into a large reservoir or conveyed on carts to the fields. *Fig. 14* shows the arrangement at Vinovo, near Turin, where the configuration of the ground is such that the process of transfer from the truck to the

cart is effected by gravitation through a large masonry reservoir. These arrangements are undoubtedly of great importance to agricultural districts, and permit of the disposal at the cheapest possible rate of sewage matter to much greater distances from the city or town than would otherwise be possible by costly works or machinery.

With regard to workshop accommodation, some of the Tramway Companies restrict their operations to small jobs, involved in the maintenance of their engines and cars, sending them to outside engineering works for any repairs of an extensive nature; while

Fig. 14.



others are equipped for all repairs required, as well as for the construction of all their rolling stock, with the exception of the engines, which come mostly from Germany and Belgium.

Rolling Stock.

The rolling-stock equipment of the different companies varies greatly in its proportion to mileage. At the nearest approximation to an average the number of engines is from 0·12 to 0·19 per mile of line worked, passenger-cars from 0·3 to 0·6, and freight-trucks from 0·3 to 0·9.

The Government requirements respecting engines for working on tramways are:—

1. The maximum working-strain on boiler-plates is not to exceed $2\frac{1}{2}$ tons per square inch.

2. The initial working-pressure is not to exceed 176 lbs. per square inch, and this allowance is to be reduced by 7·35 lbs. per square inch per annum for four years, *i.e.*, to 147 lbs. per square inch.

3. The boiler of every engine must be tested annually by hydraulic pressure, in the presence of a Government inspector, to

the extent of one-and-a-half times the working-pressure. Every fourth year the boiler must be thoroughly examined internally.

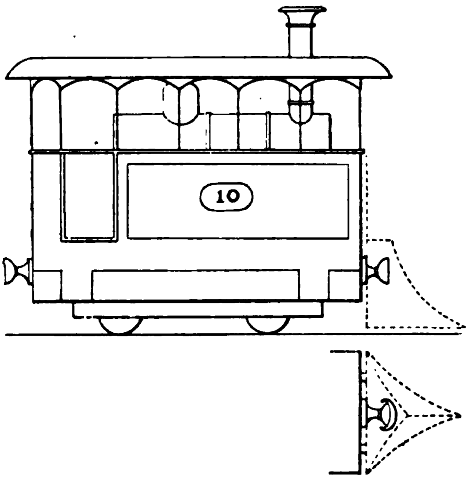
4. Boilers must be fitted with two safety-valves, one of which must be beyond the control of the driver.

5. The working parts of the engine must be cased in so as to be hidden from external view.

6. Every engine must be fitted with a brake of known power; and on lines with steep gradients, two independent brakes must be provided.

Endeavours are now being made, in view of the frequent use of soft steel for the boiler plates, to obtain an increase of the limit of strain to 3·175 tons per square inch, with an initial working-

Fig. 15.



pressure of 206 lbs. per square inch, without annual reduction so long as the annual tests show the boiler to remain in proper condition.

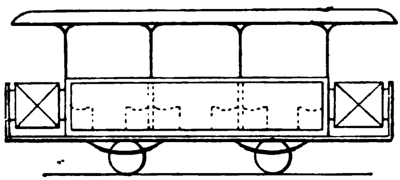
The majority of the engines have two axles; those with three axles being employed very exceptionally on steep gradients. In nearly all cases the engines are fitted with inside cylinders. The general appearance of the engine with its casing is shown in *Fig. 15.* The screen or casing hangs to within 4 inches of the rail-level. The total weight of the machine in full working order varies from 8 to 16 tons; the exceptional maximum being 20 tons. The diameters of the cylinders vary from 7 inches to 11 inches, the usual type in 12 to 14-ton engines having a diameter of 9½ inches. The average distance of the axles, from centre to

centre, is 5 feet 3 inches, with wheels 1 foot 11 inches or 2 feet 2¼ inches diameter. Neither condensers nor smoke consumers are adopted. Welsh coal is usually burnt, and wire spark-guards are fitted on the chimney.

During the winter the plains in the valley of the Po, and to an even greater extent the lateral valleys, are frequently covered with a considerable depth of snow; and to clear this, when the depth does not exceed about 18 inches, a small snow-plough, shown by the dotted line, is fitted on the engine.

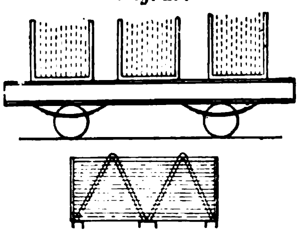
Passengers are conveyed in carriages (*Fig. 16*) providing sixteen

Fig. 16.



seats and sixteen standing-places, first class; or twenty-four seats and sixteen standing-places, second class; or a mixed type providing eight seats and eight standing-places, first class, and twelve seats and eight standing-places, second class. In a few cases longer carriages on two bogie frames have been tried, but as a rule the smaller carriages are preferred, as the train is made up more easily to suit the requirements of the moment. There is no general provision of separate luggage vans, but one compartment is usually reserved for the carriage of passengers' luggage. During the summer frequent use is made of open cars with garden seats, which are in great favour. The ordinary carriages (*i.e.*, standard gauge) weigh on an average from 3 tons to 3½ tons, and the open cars 2 tons to 2½ tons, showing a great advantage in favour of the latter during the season when they can be worked. Goods trucks generally resemble those used on the railways, their capacity ranging from 6 tons to 8 tons, and their weight (empty) varying from 2½ tons to 3½ tons for open trucks, and from 3½ tons to 4½ tons for covered vans. The platform trucks alluded to previously, for the carriage of building materials, are shown in *Fig. 17*.

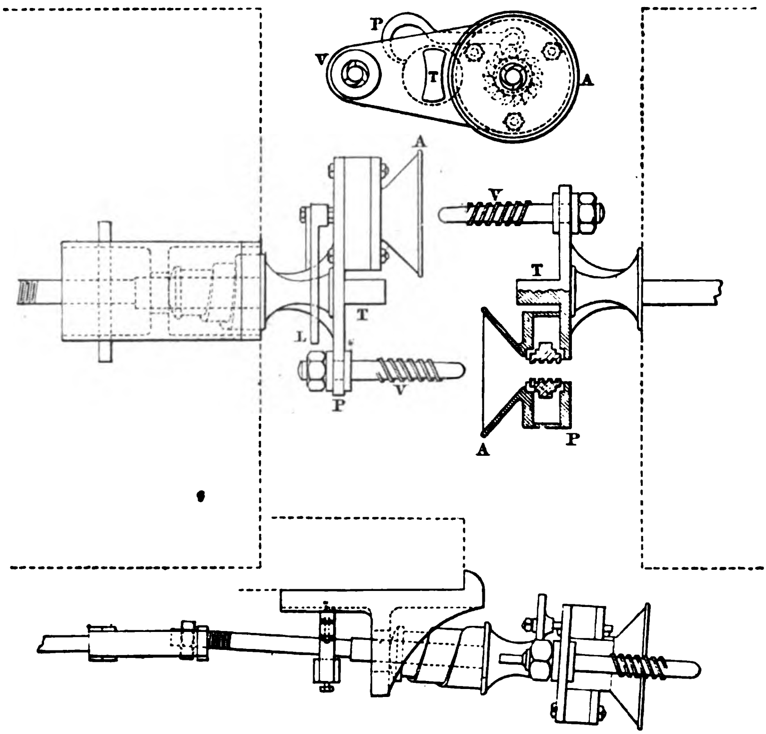
Fig. 17.



All the passenger-cars and nearly all the freight-cars on

the steam tramways are provided with brakes, so that each conductor has one close at hand. Those usually employed are chain-brakes on the passenger-cars, and screw-brakes on the trucks. Continuous brakes are only adopted in a few instances. The Neapolitan Provincial Tramways Company have compressed-air brakes, the Sicilian Tramways Company on their line from Messina the Westinghouse brake, and the Piedmontese Tramway Company the Bode brake, which acts by the force of inertia

Figs. 18.



through the central buffers. In this latter, when the driver applies the brake to the engine the buffers on all the vehicles are pressed together and inwards; and by means of special levers on the draw-bars, the brakes are closed down. Some companies have tried the Heberlein brake, but, speaking generally, hand-brakes are most commonly used, as the low speed of the trains does not justify the adoption of brakes of such a costly character. On some lines, where the companies are trying to get permission from

Government to run their trains at a speed exceeding the regulation 24 kilometres an hour, the proposal has been made to adopt continuous brakes; and this arrangement, now under consideration, will most likely be accepted by the Government.

The vehicles are usually connected by a central coupling, but of late the Prada coupling (so named after its inventor) has been extensively used. This coupling is automatic in its action; that is to say, two vehicles coming into contact become at once coupled. Upon a plate P (*Figs. 18*) is mounted at one end a double-threaded screw V, and at the other end a conical guide-cup A, terminating in a collar in which is fitted a screw-union revolving in one direction only while the levers L are in their normal position. With two cars similarly fitted, the screw V and the guide and union A of the one are respectively opposite the guide and union A and the screw V of the other. The screws V, on coming into contact with the unions, are gripped home, and the connection remains perfect until the levers L are raised, when the unions are free to revolve in the opposite direction, and so to release the coupling-screws. The system has now been working satisfactorily for several years. On the Italian steam-tramways, it must not be forgotten that at least one telegraphic connection is compulsory between all stations and stopping-places along the line. This regulation was enforced recently by the Government.

Working-Arrangements.

The original Government regulations for the trains to be run on public roads were:

Maximum weight of train, including engine	30 tons.
" length " " "	100 feet.

An alternative regulation allowed four vehicles (each of about 20 feet length), and the engine about 17 feet.

These limits have since been extended, and for trains running at from 10 to 12 miles an hour six vehicles in addition to the engine are now allowed, while still greater latitude is given if the speed is reduced.

The earliest authorizations for working steam trams on public roads limited the maximum speed to 8½ or 9 miles per hour. Later this limit was raised to 11 miles; and in many cases in recent years the speed has been increased to 12 and even 15 miles per hour. It must be noted that this is the maximum speed, which

must in no case be exceeded; and that allowance for stoppages has to be added, so that the effective or average speed is less. Experience has shown these speeds to be perfectly compatible with safely on public roads; and it is therefore possible that in some cases further concessions of higher limits may yet be made.

The fares are calculated on the following basis, viz.:

	Per Mile.
1st class	0·92*d.* to 1·07*d.*
2nd „	0·61*d.* „ 0·76*d.*

In many cases the actual fares are still lower. Considerable freedom is allowed in fixing the goods tariff; but in all cases, especially where contracts are made, the rate is extremely low.

[Details are here given of the system of ticket issues adopted; time-tables, supervision, the staff employed at stations, on the trains, and at various points; wages, and other administrative items.]

Average Cost and Earning-Power.

It is difficult to state any average cost of construction, as the works on different lines have been carried out under such varying conditions. In some cases it has only been necessary to lay the line and make good the surface; while in others, streets have had to be widened, inclines altered, and in some instances deviations from the road have been required, involving special work of a more or less costly character. The nearest possible approximation seems to be from £1,280 to £1,920 per mile for cost of construction, of which amount about £960 is required for the permanent way, materials and laying. The cost of land or of station buildings is, of course, not included in the above statement; it frequently works out at from £320 to £380 per mile, but it is practically impossible to arrive at any general average. In regard to rolling-stock, the cost of equipment varies from £450 to £570 per mile. Sundry items of supervision, compensation, workshops, telegraph or telephone, furniture, &c., come to from £100 to £200 per mile.

The average total therefore, as nearly as can be stated, is:

	Per Mile.
Construction	£1,600
Land and buildings	350
Rolling stock	500
Sundries	150
Total	£2,600

Leaving out of consideration some exceptional cases, both of bad and of good receipts, the average gross earnings are about £400 per annum per mile of line worked.

The various companies present their accounts in such different forms—some charging every item of maintenance and renewal, some setting aside a specific amount for the purpose, some including items of construction with working-expenses, and so on—that it is again extremely difficult to arrive at any fixed average of working expenses. It is apparently certain that the amount cannot be less than £125 per mile over flat country, or £160 per mile on hilly ground. The average of returns which the Author has been able to analyse give, in round figures, £300 per mile, *i.e.*, 75 per cent. of the average gross receipts. The net earnings are therefore about £100 per mile, and the average dividends (*i.e.*, on ordinary shares) are about 3 per cent. This rate has been maintained for some time, in face of continued commercial depression, and has recently shown sufficient signs of improvement to justify the anticipation of more prosperous working-conditions in the future.

The Paper is accompanied by a map showing the existing system of steam tramways in the North of Italy (Plate 9). It will be seen that several blanks in the through system of tram lines are covered by railways; so that (with or without change of cars or carriages) the transit is practically continuous.

[APPENDIX.]

APPENDIX.

BIBLIOGRAPHY OF BOOKS AND PAPERS ON LIGHT RAILWAYS IN FRANCE, GERMANY AND ITALY.

1870. "De la construction et de l'exploitation des chemins de fer d'intérêt local." Par Emile Level. *Paris.*

1873. "Traité complet des chemins de fer économiques." Par C. A. Oppermann. *Paris.*

1874. "Chemins de fer d'intérêt local." Conseil général du Département de l'Yonne. *Auxerre.*

1875. "Rapport présenté par M. Jules Martin au nom de la Commission municipale chargée d'étudier la question des chemins de fer d'intérêt local." Conseil municipal de Périgueux. *Limoges.*

1876. "Etude sur les voies de transport en France." Par Jules Brunfaut. *Paris.*

1879. "Studio sull' armamento delle tramvie in Italia." Per Luigi Luiggi. *Genoa.*

1879. "Les chemins de fer d'intérêt local sur routes." Par M. Ern. Chabrier. *Paris.*

1881. "Loi et règlements relatifs aux chemins de fer d'intérêt local et aux tramways, Août 1881." Ministère des Travaux publics. *Paris.*

1883. "L'impianto e l'esercizio dei Tramways nelle Provincia di Milano dati tecnici e statistici." Giuseppe Bianchi. *Milan.*

1888. "Strassenbahnen in Belgien, Deutschland, Grossbritannien und Ireland, Frankreich, Italien, Oesterreich-Ungarn," *etc.* Von Wilhelm von Lindheim. *Vienna.*

1889. "Arrêté préfectoral concernant le chemin de fer Decauville à forte rampe voie de 0^{m},60 installé pendant le concours régional à Laon." 12 Mai, 1888. *Corbeil.*

1891. "Réponse à la note de M. Felix Martin sur le régime des chemins de fer secondaires en France." Par M. Paul Decauville. *Corbeil.*

1891. "Conference à la Société des ingénieurs civils le 7 Août, 1891, sur les chemins de fer à voie étroite." M. H. Coste. *Paris.*

1891. "Réponse" par M. Paul Decauville. *Corbeil.*

1891. "Traité complet des chemins de fer." Par G. Hambert. [Part VI. (vol. iii.) deals with Light Railways.] *Paris.*

1892–94. "Utilité des chemins de fer d'intérêt local." Par M. A. G. Considère. *Paris.*

1892. "Guide illustré du tramway Decauville." Par H. Magron. *Caen.*

1893. "La costruzione e l'esercizio delle tramvie." Antonio Viappiani. *Turin.*

1893. "Chemins de fer sur routes. Voie de un mètre ou voie de soixante centimètres." Rapport de M. Rogier, Chambre de commerce d'Orléans et du Loiret. *Orléans.*

1893. "Monographie du chemin de fer vicinal de Dives à Luc-sur-Mer (Calvados)." *Paris.*

See also

Bibliography annexed to the Papers by Messrs. J. Carruthers, Robert Wilson and J. P. Maxwell on "Railway Steep Inclines." Minutes of Proceedings Inst. C.E., vol. xcvi., p. 141.

"Statistik der Eisenbahnen Deutschlands." Published annually. *Berlin.*

"Costruzione ed esercizio delle strade ferrate e delle tramvie." Periodical publication. *Rome and Turin.*

"Subject-Matter Index of Technical and Scientific Periodicals." Compiled by Dr. R. Rieth. *Berlin and London.*

Bibliography of Papers, &c., annexed to the title-page of the "Loi et règlements" of the French Ministry of Public Works.

"Cenni monografici" for the Exhibitions of Paris, Milan, Palermo and Turin, published by the Italian Ministry of Public Works.

"Relazione biennali sulle tramvie," published by the Italian Ministry of Public Works.

"Bulletin de la Commission Internationale du Congrès des Chemins de Fer." St. Petersburg meeting.

OBITUARY.

HERMANN LUDWIG FERDINAND VON HELMHOLTZ, who died at Charlottenburg on the 8th of September, 1894, was born at Potsdam on the 31st of August, 1821. His father, Ferdinand Helmholtz, was a schoolmaster, teaching literature specially, at the Potsdam Gymnasium; his mother (Caroline) was the daughter of a Hanoverian officer, Penne, a descendant of William Penn. He left the Potsdam school in 1838, and began the study of medicine at the Friedrich-Wilhelm Institute (Pegrinière) in Berlin. Thence he issued as *doctor medicinæ* in 1842, and took up the career of a military surgeon whereby to earn a livelihood.

But his genius having become apparent to Johannes Müller and Alexander von Humboldt, they successfully exerted their influence to secure his exemption from military duties in 1848, and obtained for him the lectureship on Anatomy at the Berlin Academy of Arts. A year later he was called to the Chair of Physiology at Königsberg, and began his memorable studies in physiological optics. In 1855 he was made Professor of Anatomy and Physiology in the University of Bonn, and in 1858 Professor of Physiology at Heidelberg. While at Bonn (strange occupation for a professor of anatomy) he performed one of his most noteworthy achievements, viz., the integration and discussion of the hydrodynamical equations expressive of vortex motion, and so laid the foundation of the modern mathematical treatment of vortices. From Heidelberg issued his great experiments and observations on acoustics and the mechanism of hearing, constituting a series of memoirs which were afterwards embodied in his "Tonempfindungen."

It was now evident that whatever else he might be, he was a physicist of the first order, and so, in 1871, he was summoned to Berlin and there installed in the Chair of Physics. He continued to hold that office until 1887, when he accepted the Presidency of the Physikalisch-Technische Reichsanstalt, then newly established by the German Government, at Charlottenburg, near Berlin.

He had been raised to nobility by the Emperor Wilhelm I in 1882, and in 1891 Wilhelm II conferred upon him the title of "Excellenz" as a mark of signal favour and personal friendship.

Helmholtz was twice married, first to Olga von Velten, daughter of a military surgeon; a son of this marriage is now

an engineer at Munich. His second marriage was with Anna von Mohl, daughter of Professor von Mohl, of Heidelberg. Their eldest son, Robert, was a physicist, and showed signs of possessing much of his father's genius; but he died in the prime of life, just as his abilities were becoming known to the world. A younger son is still studying. There was only one daughter, who is married to a son of Werner von Siemens.

The following are his books :—

1. "Wissenschaftliche Abhandlungen," published by Johann Ambrose Barth, of which the first two volumes are out and the third is in the press.

2. "Vorträge und Reden" (Vieweg & Sohn), two volumes, which have been translated into English under the editorship of Dr. Atkinson.

3. "Handbuch der physiologische Optik" (Georg Maas), a book of which a second edition has been begun.

4. "Lehre von den Tonempfindungen" (Vieweg), which has passed through two English editions, with enlargements by Mr. A. J. Ellis.

5. An edition of his lectures (Georg Maas), which unfortunately was only commenced by himself, and will now be finished by some former pupils.

In addition to these, it is well known that Taylor's scientific memoirs contain a translation of his 1847 treatise, "Ueber die Erhaltung der Kraft" (which is not to be confused with the more popular exposition of much later date, which appears in the volumes of "Popular Scientific Lectures"); that the Physical Society of London has translated and issued some of his memoirs on electrolytic and chemical subjects—on which he delivered the "Faraday Lecture" of 1881; and that Professor Tait translated his papers on vortex motion, of which an abridgment was printed in the *Philosophical Magazine* for 1867.

The work of Helmholtz lay in the departments of Mathematics, Physics, and Physiology, and his influence upon science owes much of its magnitude to the fact that he was able to apply the methods and the truths of one science to the elucidation of another. It was in the overlapping regions of science that his power was unique.

In Physiology a series of memoirs appeared between 1842 and 1856, the principal outcome of which was the determination of the velocity of nerve transmission, of the time of muscular contraction, and, most important, of the heat set free in muscular

action. He also introduced methods of investigation—some of them, previously devised by Pouillet—such as the graphical recording cylinder, the Fick pendulum, the myograph and other physical appliances, which now form the classical instruments of the physiological laboratory. He likewise tried to show that fermentation depended on something which could be filtered out by an endosmotic membrane, and through his microscope he saw some of the vibrios concerned; but the proof that fermentation could not go on without life was completed by Pasteur many years later.

The series of principal memoirs on Physiological and Physical Optics date from 1851 to 1878, and deal with a great number of subjects connected with vision, among which may be mentioned specially colour-blindness, the theory of accommodation of the eye, and optical illusion; with the very practical and early outcome—the ophthalmoscope, whereby it became possible, in 1851, for the first time to inspect the healthy human retina in action. Among other optical subjects were the visibility of ultra-violet light, the theoretical limit of microscopic vision, a discussion of theories of anomalous dispersion, the mechanism and importance of the movements of the human eye, and papers on stereoscopic vision and the principal means whereby relative distance is estimated.

In Physiological and Physical Acoustics the chief memoirs range from 1848 to 1869, and their main result is little less than a physical theory of Music, especially the explanation of the cause of dissonance and the amount of harmony in musical intervals, by means of beats. In them are given the well-known theory of combination tones, the resonance theory of musical sensation in the cochlea, and the doctrine concerning vowel sounds; all of which, though advocated with immense power and learning, have not escaped the ordeal of severe criticism. Nor can it be maintained that the theory of vowel sounds as promulgated by Helmholtz is finally complete and satisfactory. Probably the same is true of his theories of colour-blindness and of the mechanism of the perception of pitch. The doctrine of harmony seems fairly to hold its ground and to slowly make its way towards acceptance by musicians, although, since no theory of melody is so much as begun, it also will probably require supplementing and possibly modifying in the light of future knowledge.

But whether these difficult questions concerning the details of sense-perceptions and the modes of action of sense-organs are to be regarded as settled or not, there can be no question but

that the work of Helmholtz has stimulated research in these directions, and has not only increased definite knowledge of the subject, but has also furnished the means of obtaining more by working further on the same lines. His work in Acoustics has been popularised in England especially by Tyndall, whose lectures on the subject were mainly derived from Helmholtz sources.

Appropriately concurrent with the treatment of the great channels of sense-perception, Helmholtz discussed certain Psychological and Philosophical problems, such as the nature of human sense perception and the theory of cognition, the fundamental axioms of geometry, and other questions of experimental psychology—a subject in which he took a deep interest. But here a word of correction may be permitted. Because he attended a meeting of the Psychological Congress, held in London in 1892—a meeting presided over by the President of the Society for Psychical Research, many of the members of which took part in the proceedings—it has been conjectured and even publicly stated that Helmholtz was willing to lend his countenance to their investigations into facts not yet recognised by orthodox science. This, however, is a mistake, for there is high though posthumous authority for the assertion that "although always very interested in scientific experimental psychology, and working at it himself in connection with Fechner's law (on the whole regarding with more approbation the methods of Professor Strumpf than those of Professor Wundt), yet to every sort of mystical psychology he was in the strongest opposition, and severely disapproved of the mania of our century for marvels."

Under the head of Laws of Energy may be grouped a few memoirs, among which that on the development of heat during muscular contraction and the one on the conservation of energy are the chief. This last is indeed one of the most remarkable monuments of his genius, showing a profound grasp of the fundamental principles of physics, so long ago as 1847. Nothing is more astonishing than the way in which he therein takes up one branch of physics after another, and shows how an application of the universal principle suffices to disentangle new laws and relations among complex phenomena without the necessity for probing into and understanding their processes in detail. Another important though minor discovery coming under the same head was his proof that the solar heat might be, and probably was, caused by the energy of its own gravitational shrinkage or earthquake subsidence, and that it, like other stars of enormous size, might conceivably be getting hotter instead of cooler.

The memoirs on Hydrodynamics, which include some on the theory of stationary waves in viscous liquids, on discontinuous liquid motion, and other matters relating to the hydrodynamics of real as opposed to perfect fluids, were introduced in 1858 by the integration of the equations expressing the vortex motion of a liquid, and the establishment of many of the properties of vortex rings by most ingenious and clear-sighted reasoning and perception of the inner meaning of what would to many mathematicians have remained cold and irresponsive formulas.

Among the Chemical and Electrolytic papers the most important probably are those on the thermodynamics of chemical processes, wherein Helmholtz developed certain ideas analogous to those introduced in another form by Willard Gibbs, and by his doctrine of so-called "free energy" helped to lay the foundation of a future mathematical theory of chemistry. Of his electrolytic works, probably the most important are the experimental investigations into the behaviour of a gas-free cell, and the verification in actual fact of conclusions deduced from the laws of thermo-chemistry—conclusions which, on a superficial estimate of known facts, seemed to be, and by some were supposed really to be, at variance. The electrolytic views expounded in the Faraday lecture, though simple and helpful enough, were not really beyond those at which other disciples of Faraday had arrived about the same time, and did not therefore advance the boundaries of knowledge further than must inevitably be the result of a clear and authoritative exposition.

His application of the theory of electric boundary-layers to electric endosmose and electro-capillary phenomena generally, and his explanation of the electrification observed by Quincke, Edlund, and others, when streams of liquid flow along narrow tubes; his application of the second law of thermodynamics to complete Lord Kelvin's theory of the calculated electromotive force of a voltaic cell in terms of its rate of variation with temperature, are all matters of considerable interest.

It will be observed that in every one of the great branches into which his profound researches have been classified, each is characterized by some epoch-making discovery or invention or memoir of classical importance, forming a starting-point for further research—a basis or method for future discovery. But there is one group of memoirs, and that the most extensive, not yet touched upon,—those relating to Electrical Theory. Out of the influence and inspiration of Helmholtz' electrical teachings arose the brilliant work of Hertz, and that alone entitles them to more than respectful consideration and gratitude.

To what manner of man is it that these great discoveries and brilliant inspirations are vouchsafed? Most fortunately there is a beautiful self-drawn portrait, an autobiographical sketch, which will probably be as highly prized by posterity as anything that this great man achieved; for in it he glances back over his own past career and quietly asks, how came it that I did this and that? how comes it that this that I did is so amply recognised? wherefore is it that after all men call me great? And as answer he is shown going about his work thinking the thoughts that come to him, keeping his mind open and receptive, and his brain as clear and unembarrassed as this busy century would let him, happy in belonging to the studious German nation, which takes pride in a learned man and does not wish him to enter politics or to adopt any other career than the one for which heaven has fitted him, but leaves him to flourish, and to obtain such honour as it can give, in his own true sphere. A childlike simple man, to whom great thoughts come easily and do not overburden him. They come to him as he walks or while he is waking. "They steal into the line of thought without their importance being at first understood." Sometimes "they occur suddenly without exertion like an inspiration," but "they never come at the desk or to a tired brain." "I have always so turned my problem about in all directions that I could see in my mind its turns and complications and run through them freely without writing them down. But to reach this stage was not usually possible without long preliminary work. Then after the fatigue of this work had passed away, an hour of perfect bodily repose and quiet comfort was necessary before the good ideas came." Then he goes on to say that, as happened to Goethe and to Gauss, his good ideas often came in the morning on waking; and that to himself they also frequently came, as at Heidelberg, "when comfortably ascending wooded hills in sunny weather." But, on the other hand, sometimes the delightful moments of fruitful thought would not come, and "he would gnaw for weeks or months at a refractory problem in his mind, until a sharp attack of headache released him from the strain and set him free for other work."

It is interesting to realize how the achievements of genius appear to their originator, and upon this also Helmholtz lets some light. When expressing surprise at the honours heaped upon him and at the high estimate placed upon his work, he says :—

"I know how simply everything I have done has been brought about; how scientific methods worked out by my predecessors have naturally led to certain results, and how frequently a fortunate circumstance or a lucky accident has

helped me. But what I have seen growing from small beginnings, through months and years of tentative work, all that suddenly starts before you like Pallas fully equipped from the head of Jupiter; a feeling of surprise has therefore entered into your estimate but not into mine."

His remarks on his early aptitudes and education are very instructive. He says:—

"In my first seven years I was a delicate boy, for long confined to my room and even to bed, but I had a strong inclination towards occupation and mental activity. My parents busied themselves a good deal with me; picture-books and games, especially with wooden blocks, filled up the rest of the time. The first laws of phenomena I got to know were in geometry. From the time of my childish playing with wooden blocks the relations of special proportion to each other were well known to me from actual perception. What sort of figures were produced when bodies of regular shape were laid against each other I knew well without much consideration. When I began the scientific study of geometry, all the facts which I had to learn were perfectly well known and familiar to me, much to the astonishment of my teachers."

"One thing, however, was wanting in geometry, it dealt exclusively with abstract forms of space, and I delighted in complete reality; . . . . the first fragments of physics which I learnt in the gymnasium engrossed me much more closely than purely geometrical and algebraical studies had done. Here was a copious and multifarious region, with the mighty fulness of nature, to be brought under the dominion of a mentally apprehended law. And in fact that which first fascinated me was the intellectual mastery over nature, which at first confronts us as so unfamiliar, by the logical force of law."

"I must confess that many a time when the class was reading Cicero or Virgil, both of which I found very tedious, I was calculating under the desk the path of rays in a telescope; and I discovered even at that time some optical theorems, not ordinarily met with in text-books, but which I afterwards found useful in the construction of the ophthalmoscope."

Some other reminiscences about his mental aptitudes and disabilities are likewise full of interest and instruction. "Reading," he says, "came pretty easily; but a defect of my mental organization showed itself almost as early, in that I had a bad memory for disconnected things." He had a difficulty at first even in distinguishing between left and right; and "afterwards, when at school I began languages, I had greater difficulty than others in learning words of irregular grammatical form and peculiar idioms. History as then taught to us I could scarcely comprehend. To learn prose by heart was martyrdom." On the other hand, poetry, so long as it was full of consecutive thought and good rhythm, he could learn readily enough; and, later on, he could repeat whole "books of the Odyssey, a considerable number of the odes of Horace, and large stores of German poetry." His father was an enthusiast for poetry, particularly for the classic period of German literature, and trained the boys in composition on set themes alternately in prose and in verse; and so,

"even if most of us remained indifferent poets, we learned better in this way than in any other I know of, how to express what we had to say in the most varied manner."

That he did not stand out specially in ordinary school studies was to be expected. "Mathematics was always regarded in the school as a branch of secondary rank. In Latin composition, on the contrary, which then decided the palm of victory, more than half my fellow-pupils were ahead of me."

Proceeding to his student career, which began in medicine, because Physics was regarded as a subject in which a living could not be made, he acknowledges the inspiring influence of Johannes Müller (in whose laboratory he had worked along with du Bois-Raymond, Brücke, and Ludwig as co-students), and relates how he was led into cogitation and arguments on the deepest problems, such as those connected with the question of a "vital force." In the course of this struggle, he perceived that many vitalists were practically regarding an animal as a perpetual-motion machine, out of which more work could be got than energy was put in, and so from it arose his essay "Ueber die Erhaltung der Kraft," which he wrote for the benefit of physiologists; but, to his surprise, he found that the physicists themselves were unprepared for it, and some of them were inclined to quarrel with it as a "fantastical speculation," analogous to those of Hegel against which they were accustomed to tilt.

He went on with investigations into the heat of muscular action, and into the chemical decompositions occurring in the animal organism considered from the energy point of view. It was on account of these researches that Johannes Müller was able to prevail on the Prussian Ministry of Instruction in early days to establish him in Berlin as successor to Brücke, and immediately afterwards to send him to the University of Königsberg.

"A University Professor," he says, "undergoes a very valuable training in being compelled to lecture every year on the whole range of his science, in such a manner as to convince and satisfy the intelligent among his hearers—the leading men of the next generation." This, doubtless, is true everywhere, but must be especially true in an educated country like Germany, where the youths come from school sufficiently instructed in the rudiments of knowledge, so that a foundation for future real study has already been laid before they reach the University.

"In preparing my course of lectures I hit directly on the possibility of the ophthalmoscope, and then on the plan of measuring the rate of propagation of excitation in the nerves."

The ophthalmoscope, as rigged up with spectacle lenses and other ordinary means, "was at first difficult to work; and without an assured theoretical conviction that it must work I might perhaps not have persevered. But in about a week I had the great joy of being the first who saw clearly before him a living human retina." The retinal image is formed by the eye's own lens, and the invention consists in recognising this fact and in devising means for making the image visible.

Helmholtz ascribes much of his success to the circumstance that "possessing some geometrical capacity, and equipped with a knowledge of physics, he had found in physiology a virgin soil of great fertility, while on the other hand he was led by the consideration of vital processes to questions and points of view which are usually foreign to pure mathematicians and physicists." The "geometrical" method of regarding things—in other words, a clear mental grasp, without symbols, of the conditions of a problem—must be an essential to a real physicist as distinct from a mere mathematician; but there is no need to press the adjective geometrical to mean more than what might be still more generally expressed as vivid full-bodied mental representations.

His successes and the veneration of contemporaries (which must have been an extremely marked feature in his later life) were far from leading him into an over-estimate of himself or into self-admiration.

"I have often enough seen how injurious an exaggerated sense of self-importance may be for a scholar, and hence I have always taken good care not to fall a prey to this enemy. But it is only needful to keep the eyes open for what others can do, and what one cannot do oneself, to find that there is no great danger; and as regards my own work, I do not think I have ever corrected the last proof of a memoir without finding, in the course of twenty-four hours, a few points which I could have done better or more carefully."

"The writing out of scientific investigations is usually a troublesome affair; at any rate it has been so to me. Many parts of my memoirs I have rewritten five or six times, and have changed the order about until I was fairly satisfied. But the author has a great advantage in such a careful wording of his work. It compels him to make the severest criticism of each sentence and each conclusion. . . . . I have never considered an investigation finished until it was formulated in writing completely and without any logical deficiencies."

One of his pupils, Dr. Kronecker, says that his estimate of the value of popular exposition was a high one, and he never thought it beneath him to lecture and write in a popular style. He was able to explain difficult problems in mathematics, in physical science, or in philosophy, in a clear and beautiful manner. He never sank to the level of his audiences, he drew them up towards himself.

For music and natural scenery he was an enthusiast, and pilgrimages to Baireuth and thence to the Engadine and the Tyrol were frequent.

At the age of seventy-three he was still in possession of much power of work, as well as of ripe judgment and inspiring influence over younger men, but the supposed exigencies of a formidable journey to Chicago have sufficed to deprive the world of the later years of this magnificent life. It will serve no purpose now to inquire why such an unsuitable and useless journey was ever permitted or enforced. The report that such a journey was to be undertaken was received in England with regret, only too well justified by the fatal consequences. The services of such a man are not to be limited by national boundaries nor acknowledged with constricted gratitude; he belongs to the world and to nothing less. The possession of a great genius is a great responsibility, not every nation is worthy of it. Fortunate were the German people in receiving into their midst so indomitable and persevering a worker, so single-hearted and estimable a man; and they have proved themselves well worthy of the trust. Throughout his later life they held him in highest honour, and they provided him with material resources such as no other nation at the same epoch was likely to bestow. Honourable his life has been, both to man and to nation; and the world, though blind to many things of high and noble import, has in this case no cause to regret that the man came before his time, or that he spoke to a faithless and perverse generation.

Von Helmholtz was elected as an Honorary Member of the Institution on the 9th of January, 1894.

On receiving the intimation of his nomination for election, he despatched the following telegram:—

"Charlottenburg, December 15th, 1893, 6–5 P.M.

Secretary of Institution of Civil Engineers,
JAMES FORREST, ESQ.,
25, Great George Street, Westminster, London.

Greatly honoured I gratefully accept nomination for election as Honorary Member of your great Institution.

HELMHOLTZ."

FERDINAND DE LESSEPS, Honorary Member, whose name has become indissolubly connected with the promotion, design, and construction of one of the most celebrated engineering works the world has ever possessed, was born at Versailles on the 17th of November, 1805.

His father was an active functionary of the French State, chiefly in the diplomatic service, and through his influence young Ferdinand received a free education at the College of Henry IV. in Paris. Probably nothing could have been farther from the idea of his parents and friends than that he would achieve greatness in an engineering sphere; he started in working life, while quite a youth, in the diplomatic career, and appears to have had much varied and useful employment therein till he was nearly fifty years old. The only way in which his experience seems to have led in the direction of his after-life was being appointed Vice-Consul at Cairo, and residence in Egypt from 1831 to 1838. During the great plague there in 1834–5, which carried off one-third of the population, the heroism and devotion he showed gained for him the decoration of a Chevalier of the Legion of Honour. For similar brave services, during the bombardment of Barcelona in 1842, he was promoted to the grade of Officer, and obtained other distinctions. After a mission to Rome, in which some misunderstanding occurred, he retired into private life, residing (in a château formerly occupied by Agnes Sorel, the beautiful favourite of Charles VII.) at La Chesnaye, in the ancient Province of Berry, Central France.

It was only in 1854 that an event occurred conducing to the work which has made him celebrated. One morning in August of that year, while on the roof of a house he was building, in the midst of scaffolding and workmen, a newspaper was put into his hand informing him of the death of Abbas Pasha, and of the accession to the Viceroyalty, in Egypt, of his former patron and friend, Mohammed Saīd. In an instant the workmen and their work were forgotten, and he was taking steps to congratulate the new Viceroy, and proposing at once to go over to Egypt again.

The idea which flashed into his mind so suddenly and so powerfully, was a scheme he had formerly cherished for the improvement of the communication between Europe and India. When he was sent to Egypt in 1831, he had, according to the custom of the time, to pass quarantine at Alexandria; and in order to amuse him during his long incarceration, the Consul brought him Denon's great work on the French Expedition into

Egypt, in which he read of the various attempts that had been made to unite the waters of the Mediterranean and the Red Sea, from the time of the Pharaohs to that of Napoleon; with a report on the subject generally by the engineer of the expedition, M. Lepère.[1]

In connexion with this subject, during his subsequent residence in the country, he was greatly struck with the history of the overland route through Egypt to India, which had been then established by the almost superhuman energy and perseverance of Lieutenant Waghorn. This worthy man had devoted the best years of his life, and all his pecuniary means, in defiance of the opposition of the authorities most interested in the object, to the establishment of this route, the great advantages of which, during the residence of de Lesseps in Egypt, were just beginning to be generally known.

De Lesseps appears to have been fascinated by the noble behaviour of Waghorn, which he considered as a model for his own guidance; and connecting the already accomplished land-passage of the isthmus with the ancient ideas of the passage by water, he appears to have resolved to imitate the bold lieutenant in his own efforts to introduce a grander enterprise. "No wonder," says a biographer, "that the projector of the water-route should speak with tender sympathy of the projector of the overland journey; and there is something touching in the picture of the future maker of the canal, watching thoughtfully, at Alexandria, the impassioned courier hurrying past him on his way while he himself was maturing his own gigantic scheme."

Although there is no doubt that he studied the subject well while in Egypt, he does not appear to have seen his way to doing anything actively about it till after his return to France. In 1852 he had drawn up a programme which he translated into Arabic, and through an old friend, the Dutch Consul General, he got it laid before Abbas Pasha, then Viceroy. He said:

> "I must own that my scheme is still in the clouds, and I cannot conceal from myself the fact that so long as I have only myself to believe in its possibility there is no chance of getting the public to accept it. The idea is to cut a passage through the Isthmus of Suez—which has again and again been proposed since the old historical times, and perhaps for that reason has been thought impossible. I send you a Memoir," &c., &c.

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[1] M. de Lesseps wrote and published, at various times, a large mass of matter on the subject of the Canal, much of which has been translated into English. Many of the particulars in this notice are taken from "The Great Canal of Suez," by Percy Fitzgerald. London, Tinsley, 1876.

Abbas Pasha was a voluptuary, not inclined to entertain such schemes, and de Lesseps got the matter laid before the Sultan, who, however, replied it was the affair of the Viceroy. "Under these circumstances," said M. de Lesseps, "I must only let my project sleep. While waiting a more favourable time, I shall take to agriculture and to the working of a model farm." And it was in pursuance of this resolve that, two years later, he was superintending the builders at La Chesnaye, on that August morning in 1854.

From that moment he never rested till the completion of the canal. Mohammed Saïd had been his warm and intimate friend in his Egyptian time, and he had strong hope that the new Viceroy would interest himself in the canal scheme. The answer invited M. de Lesseps to meet the Pasha in November; and he landed on the 7th at Alexandria, where he was sumptuously received. On the 15th he unfolded his plan and answered all enquiries, after which the Pasha said, "I am satisfied, and I accept your scheme. We shall arrange all the details during our journey to Cairo; but understand that it is settled and you may count upon me."

On the 25th the Viceroy called a meeting of the public functionaries and foreign Consuls at Cairo, and announced to them the project, and on the 30th the "Concession" was formally signed. M. de Lesseps now determined to survey the country more accurately than had yet been done, and he took with him two French engineers, Mougel Bey and Linant Bey, who had long practised in Egypt, and were well acquainted with the locality this occupied about three weeks, and the results were perfectly favourable. The successful prospects of the undertaking were now attracting notice, and M. de Lesseps began to receive offers of help from all quarters. But he quoted advice once given him by Mehemet Ali, who said, "Always keep this in mind, my young friend; when you have any important scheme on hand, depend on yourself alone. If you have a partner, that is one too many."

So far all appeared *couleur de rose.* But more gloomy prospects now began to arise. The English Consul had not joined in the general enthusiasm, and had plainly told the Viceroy that "he was going too fast;" moreover, clouds began to lower in the direction of the Porte. M. de Lesseps knew that the English influence, if unfavourable, would be strongly exercised in the Turkish quarter, and he at once started for Constantinople, arriving there in February, 1855. His scheme was laid before

the Sultan, and the impression at first seemed favourable; but this proved to be a mistake, owing, as it afterwards came out, to the opposition of England; for in June a despatch from Lord Clarendon was received disapproving of the proposal on strong grounds, partly from political motives, and partly from doubts as to its feasibility. And it is somewhat humiliating to have to record that, from this time onwards, the most formidable opposition to the construction of the Canal came from the British nation, which was afterwards chiefly to benefit by it.

M. de Lesseps determined boldly to face the enemy, and he went straight to London, where he found his worst fears realized; for though the mercantile community encouraged him, the Government, as represented by Lord Palmerston and Lord Clarendon, was strongly inimical.

He succeeded, however, in getting, in October, an independent Commission appointed to survey the Isthmus and report on the scheme. It consisted of two distinguished English engineers, Mr. Maclean and Mr. Rendel; M. Conrad, the eminent chief of the Waterstaat in Holland; Sig. Negrelli, director of public works in Austria; and other competent persons appointed by European powers. Mr. Charles Manby (of this Institution) and Mr. Lieussou, of Paris, were appointed secretaries. On the last days of October, 1855, the Commission met in Paris,[1] after which a deputation of them made an expedition to Egypt occupying nearly a month, the expenses, about £12,000, being paid by the Viceroy. The Commission made a preliminary Report in January, 1856, which was followed by a more complete one in June; both were entirely favourable to the scheme, recommending, in fact, the plans which were afterwards carried out.

But in spite of this approval, objections were not wanting. In January, 1856, an article appeared in the *Edinburgh Review*, examining, with much pretension to technical knowledge, the whole question of the communication between the two seas, and strongly discouraging M. de Lesseps's proposal. This article was ably answered by M. Barthélémy St. Hilaire in the *Revue Britannique* of April in the same year.

There were many subsequent discussions, M. de Lesseps being ubiquitous in his exertions to keep up the interest in the affair. In London he was presented to the Queen, and had a long com-

[1] Mr. Rendel (who died in 1856) was prevented from attending by ill-health, and he was represented at the meeting by his son, Mr. George W. Rendel, and one of his chief assistants, Mr. William Pole.

munication with Prince Albert; the Geographical Society entertained him and listened to his explanations. He determined to get up meetings throughout Great Britain, and it is said he held thirty-two of such meetings in forty-five days, visiting almost every important town in the three kingdoms. And though his knowledge of the language was but imperfect, his energy and determination caused him to be always well received. He said, "In spite of my jumble of English words drowned in French expressions, every one applauded, wishing to show that they followed my meaning." His enthusiasm carried him on in this determined war with the Government, and between 1854 and 1858 he is said to have travelled 10,000 leagues every year. He appears to have been almost superstitiously confident of ultimate success; indeed, he said that when he saw a rainbow stretching across the Isthmus it presented to his mind a future junction of the East and West, and a luminous meteor, shooting over one of the lake beds on the first day of his survey, showed him the line he should follow.

On the 7th of July, 1857, the matter came before the English Parliament, a question being put as to whether Government would use its influence with the Sultan to favour the measure. Lord Palmerston spoke strongly against the Canal, characterizing it as a "bubble scheme." On the 17th the debate came on again, when a more serious opposition to it appeared in opinions publicly expressed by one of the most respected English engineers, no less a personage than Robert Stephenson. This eminent man had had a good deal to do with Egypt, having been engaged by Abbas Pasha to construct the railway forming the improved overland route from Alexandria by Cairo to Suez. Before this, however, namely in 1847, he had, at the suggestion of Linant Bey, paid some attention to the Suez Canal, having investigated the subject in conjunction with M. Paulin Talabot, a French engineer, and M. Negrelli, an Austrian engineer. The French engineers who were in Egypt at the time of the invasion, about 1800, appear to have adopted and circulated an opinion of the ancient writers, that there was a difference between the levels of the Mediterranean and the Red Sea of something like 30 feet. This assertion had been challenged on physical grounds by Laplace and Fourier. In order to determine the point the three engineers caused a careful levelling to be made, which proved that there was (as might be expected) no difference between the levels, except what was caused by the tides. Mr. Stephenson's view was that if such a difference had existed, a current could be established,

constantly running, which would keep the Canal clean; but without such a current he and his associates did not believe the canal could be made, or if made, could be kept open afterwards. The idea was accordingly abandoned, and M. Talabot wrote, at a later time, a report recommending a different scheme.

When, therefore, on the 17th of July, 1857, the project of de Lesseps came before Parliament, Mr. Stephenson made a long speech condemnatory of it, explaining his views and frankly declaring the proposed Canal in his opinion to be an impracticable scheme.[1]

About this time the Government appears to have thought it desirable to institute some inquiries on its own behalf, and accordingly the Admiralty sent Captain T. Spratt, C.B., to Egypt for the purpose. He wrote two reports, dated 30th January and 9th July, 1858. His conclusions were adverse to the project, and he warned the commercial interest against risking their millions in the undertaking. He contended that the material brought to the sea by the great river Nile, would be carried eastwards by the prevailing winds and currents, and would accumulate against the piers or jetties proposed to be built to form a harbour at Port Saïd, and so would prevent the maintenance of a sufficient depth of water there. His reports were industriously circulated to support the inimical views of the Government, but the reasonings were strongly controverted at the time by Mougel Bey, and were afterwards entirely disproved by Mr. Hawkshaw.

After more negotiations, and constant agitation on the part of de Lesseps, continually hovering between Constantinople and London, the matter was again brought before the British Parliament. On the 26th of March, 1858, Lord Palmerston having retired, the new Premier, Mr. Disraeli, was asked whether the British Government "considered it desirable to persevere in its opposition to the Canal, now that all the nations of Europe favoured the scheme?" He replied that his opinion was that "it was a most futile attempt, totally impossible to be carried out, and that, even if it were feasible, the operation of Nature would, in a short time, totally defeat the ingenuity of man." De Lesseps had hoped that the retirement of his old avowed enemy, Lord Palmerston, would have been of service to him, but he found himself no better off than before.

The debate was resumed on the 1st of June, 1858, when Mr.

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[1] See "The Life of Robert Stephenson," by Jeaffreson and Pole, 1864, vol. ii. pp. 148–152.

Roebuck moved and Mr. Milner Gibson seconded, "that in the opinion of this House the influence of the country ought not to be used in order to induce the Sultan to withhold his assent to this project." This brought on an animated debate. After the mover and seconder had eloquently pleaded in support of the scheme, Mr. Robert Stephenson made another speech reiterating his former objections. He even denied that the construction of the Canal was physically possible; and he stated, in conclusion, "his opinion that if it was attempted at all—which he hoped it would not be, or at least not with English money—it would prove an abortive scheme, ruinous to its constructors." Mr. Gladstone spoke warmly in favour of the canal, and objected to English influence being exercised against it; he supported the practicability of the plan, and exposed the political fallacies urged on the other side. Lord John Russell, Mr. Bright, and others joined in the debate, and Mr. Disraeli replied at great length; the result being that Mr. Roebuck's motion was rejected by the large majority of 228 in a house of 290 members.

This settled the conviction in the mind of de Lesseps that he must not hope longer for the concurrence of England. He had nothing left but to go back and to do his best to brave the opposition thus manifested; and after a short tour on the Continent he arrived in Paris at the end of August 1858, with the view of formally constituting his company. By the end of the year he had got this done. It was to be a company of the French pattern known as "Société Anonyme," its social seat being at Alexandria, but its legal and administrative abode in Paris. The capital was £8,000,000 sterling in 400,000 shares of £20 each, and during the construction 5 per cent. interest was to be paid on the capital subscribed. Prince Jerome Napoleon was appointed "Protector," the President was de Lesseps himself, and the title was "Compagnie Universelle du Canal Maritime de Suez."

This object being accomplished, the next effort of the promoter was actually to begin the construction of the Canal, and he now made his way to Egypt. He encountered many difficulties in the first steps of procuring possession of the land, but on the 25th of April, 1859, surrounded by a staff of 150 workmen and employés, de Lesseps gave the first blow with the pick-axe, and turned the first spadeful of earth on the beach of the Mediterranean at the proposed terminus of the Canal. Not long afterwards from 25,000 to 30,000 men were at work, and the construction of the Canal had really begun.

It is not the object of this notice to describe the Canal, or even

to chronicle in any detail the progress of the construction; such information may be easily obtained from other sources. But a brief account may be useful to make more intelligible the personal narrative.

The Canal is about 100 miles long, from the south shore of the Mediterranean to the north end of the Red Sea. Between these two points there is a natural narrow line of depression or indentation, in which lie several wider and deeper depressions below the sea-level, forming the basins of lakes that have long been dry. It had therefore always been seen that this long depression would be the most natural line for a channel connecting the two seas. There are only two points along the line at which the ground rises much above the mean sea-level, namely, at El Guisr and Serapeum; the former being 59 feet and the latter 36 feet elevation.

The Canal begins near a point on the Mediterranean formerly called Pelusium, and as an entrance to it an artificial port has now been made, named Port Saïd in honour of the Khedive. The harbour is formed by two strong piers or breakwaters, each above a mile in length, built out into the sea with large blocks of concrete. From Port Saïd the Canal is cut for about 29 miles through the shallow depression of Lake Menzaleh, and then 20 miles partly through ground flooded at the time of inundations, and partly through the low hill at El Guisr, to Lake Timsah, near which has been formed the new little half-way town of Ismaïlia. Then a land-cut of 12 miles through the slight rise at Serapeum brings it to the northern bank of the Bitter Lakes, which form a great basin 22 miles long and in some places about 6 miles wide. From the southern end of this basin another solid cut and a passage along the edge of a small lake, together about 18 miles, bring it to the Red Sea at Suez. There are 60 miles of passage through lakes and 40 miles cut in land.

The cross-section of the Canal has varied in different places and at different times, as, in the first instance, smaller dimensions were adopted for the heavier excavations to save first cost. At the time of opening, the normal water-section was fixed at 72 feet wide at the bottom and 26 feet deep. For 22 miles the slopes were 2 to 1 with horizontal benchings, giving a width of 196 feet at the surface; but for the remaining 78 miles the slopes were flatter, and the benchings wider, giving a surface width of 327 feet. At intervals of 5 or 6 miles there are "sidings," or side-basins, to enable vessels to pass one another; and provision was made generally for widening the Canal, when considered desirable.

In addition to the maritime undertaking it was an important part of the scheme to form a separate canal, to bring the fresh water of the Nile to the line of the operations, partly for the workmen during the construction, but chiefly for the supply of the district generally, and the consequent improvement of the territory. The ideas as to its arrangement had varied several times, but the final plan was to take the Nile water from the *barrage* near Cairo, conveying it to Suez and to Ismaïlia, whence, by pumping arrangements, ample supplies could be given wherever required, extending by pipes even to Port Saïd.

The Fresh-Water Supply was not properly part of the Company's permanent Works; it was done by them, but was paid for by Egyptian funds.

Resuming the brief history of the construction of the Canal, which, as stated, was begun in April 1859—by the end of 1862 the two piers forming the entrance at Port Saïd had been partly built, and the excavation of the Canal had so far advanced that a water communication from the Mediterranean to Lake Timsah had been opened for boats of small draught, and many houses and workshops had been constructed. The cuttings through the hill of Serapeum gave great trouble, but were at last overcome by getting large dredgers to work at them. These were stupendous machines, and were used in such numbers that an enormous amount of material was dredged away in very little time. Thousands of men were also at work superintended by French officers.

In July 1862, the Viceroy Mohammed Saïd Pasha, being in England, determined to get the benefit of further technical advice from English skilled authorities about the Canal; and it is remarkable how many engineers or naval and military officers have reported at one time or other on the subject. The opinions of Robert Stephenson and of Captain Spratt, already mentioned, were given before the Canal was begun. Now, it being actually in progress, the Viceroy commissioned Mr. (afterwards Sir) John Hawkshaw, then President of this Institution, to visit the works and to report his opinion thereon to the Egyptian Government. Mr. Hawkshaw accordingly went to Egypt in October, spent some time there, and presented his Report on the 3rd of February, 1863. He described accurately what had been done, and approved generally both the design and the construction. In recommendations for the future he laid great stress on the completion and perfection of the Fresh-Water Canal and its dependencies. He warned the

Company of the possible existence of rock in the main line (a prophecy afterwards singularly fulfilled), and gave other useful suggestions in regard to details of the excavation. He also paid considerable attention to the question of the future permanence and maintenance of the Canal and its entrances. He noticed the objections that had so formidably arisen on this score, and discussed them thoroughly.

His most important conclusions were summed up in the two following sentences:—

"First, as regards the engineering construction, there are no works on the Canal presenting on their face any unusual difficulty of execution, and there are no contingencies, that I can conceive likely to arise, that would introduce difficulties insurmountable by engineering skill.

"Secondly, as regards the maintenance of the Canal, I am of opinion that no obstacles would be met with that would prevent the work, when completed, being maintained with ease and efficiency, and without the necessity of incurring any extraordinary or unusual yearly expenditure."

This document, coming from such an authoritative source and being founded on such a thorough examination of the facts, had great influence on public opinion. It was translated into French and widely circulated, and was much quoted in future proceedings. De Lesseps was of course much delighted with it, and on many occasions expressed publicly his indebtedness to its Author.

The Sultan paid a visit to the work about this time, as did also an ambassador from England, and both seemed pleased with its prospects.

But, in spite of these fair anticipations, new troubles arose, of so serious a character as not only to delay the construction materially, but almost to threaten its stoppage altogether. On the 18th of January, 1863, Mohammed Saïd, the old friend of M. de Lesseps, and his patron in the original projection of the Canal, died, and "there arose up a new king over Egypt, which knew not Joseph"—Ismail Pasha. This Viceroy was not inclined to view complacently a great French company in possession of an important position in his realm; he chafed under certain pecuniary engagements to which his predecessor had bound him, and he was short of money. The sweet-water channel, passing through the heart of his kingdom, far away from the Suez Canal, was bound up with territorial privileges, which were irksome and which he wanted changed. But there was another subject that gave him the means of persecuting the Company, namely, an agitation (partly attributed to British influence) which had some time previously been set on foot, ostensibly on philanthropical grounds, for

stopping the forced labour hitherto allowed. This had been threatened in 1861 and 1862; but now the Company received actual notice that the forced labour would be withdrawn—the result being that the work languished, and was indeed almost abandoned for two years. And, with a less determined spirit directing the concern, it might have turned out to be one of those hopeless abandoned follies which become wonderful in after-history.

As, however, the provision of native labour had been an important article of the original agreement, the Company's claim could not be altogether ignored, and, after much discussion, it was agreed to refer the whole matter to the arbitration of the French Emperor. At the same time, he was asked to settle some other alterations of the former agreement in regard to matters external to the main scheme, having to do with the construction and use of the Fresh-Water Canal, and the property of the land on the line of its route. His award was given in July, 1864, and it comprised indemnities to be paid to the Company, of 38,000,000 francs for the loss of forced labour, and 46,000,000 francs for the work done and rights abandoned on the Fresh-Water Canal, in all £3,360,000.

Hitherto, through the distracting effect of the European political discussions and negotiations, chiefly fomented by English suspicions, no formal sanction of the Canal had ever been given by the Porte; but now, after twelve years' delay, the long-promised Firman, dated 12th of March, 1866, was dispatched to the Khedive, recognising the "Compagnie Universelle" for the piercing of the Isthmus of Suez, and approving all the arrangements and agreements now made for the same.

In April, 1867, the subject was brought before this Institution. Many years previously, *i.e.*, in May, 1851, a Paper by Mr. Joseph Glynn, F.R.S., M. Inst. C.E., "On the Isthmus of Suez and the Canals of Egypt," had been read, in which the possibility of a direct canal through the Isthmus was mentioned as having been recommended in a report by Colonel Chesney, R.A., in 1830.[1] The discussion on Mr. Glynn's Paper is noteworthy as containing a long description by Mr. Robert Stephenson of his early studies of the subject.

In 1867, when the Canal was approaching completion, it hap-

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[1] A note added to this at a later time (Minutes of Proceedings Inst. C.E., vol. x. p. 375) mentions M. de Lesseps's project and the International Commission of 1855.

pened that Colonel Sir William T. Denison, K.C.B., of the Royal Engineers, on his return from India, examined the works, and he communicated an account of them to the Institution in a Paper[1] read on the 16th of April in that year, which gave rise to a discussion occupying two evenings. Sir William's Paper presented a good view of the works at that period, and his own opinion was favourable to the successful completion of the work, but he thought the cost of maintenance would probably be considerable. In the discussion which followed, Mr. Abernethy (who had also examined the works) expressed a favourable view; but several other engineers repeated objections of various kinds that had been brought against the Canal, and the Astronomer Royal, Sir George Airy, mentioned several points of scientific interest connected with it.

The works were now quietly but effectually pushed on by energetic contractors, with powerful machinery and well-paid labour. On the 24th of March, 1869, the Prince and Princess of Wales, who were in Cairo, visited the Canal; and M. de Lesseps invited them to witness the ceremony of letting the waters of the Mediterranean into the huge reservoir (already a part of the Canal) of the Bitter Lakes.

The waterway being at length completed for the whole distance, though still not for its full depth, the 17th of November was appointed for the formal opening, and on the 15th there assembled at Port Saïd the Viceroy, with his large suite, the Empress of the French, the Emperor of Austria, the Crown Prince of Prussia, the Grand Duke Michael of Russia, the Prince of Sweden, the Crown Prince and Princess of Holland, the Prince of Hesse, Abd-el-Kader, and a host of diplomatic officers and distinguished personages from other countries, to assist in the festivities, all being received and entertained by the Egyptian Government with great splendour.

On the 16th religious benedictions were pronounced on the work by the clergy of the Roman Catholic, the Greek, the Coptic, and the Mohammedan religions, each in its own mode; and on the 17th the formal opening of the Canal took place by the passage through it of a large number of ships, headed by the Imperial yachts, and war-ships of several nations, altogether some forty in number; and thus the connexion between the two seas became an accomplished fact.

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[1] Minutes of Proceedings Inst. C.E., vol. xxvi., p. 442.

The Canal being now open for public traffic, it was natural that accounts of it, with opinions and criticisms by competent judges, should be published to the world.

On the 27th of December, 1869, Mr. J. F. Bateman, F.R.S., who had attended the opening, wrote a notice of the work which was afterwards printed in the Proceedings of the Royal Society (No. 116, 1870). He gave a concise history, pointing out the strong opinions that had, down to that time, been held to its disadvantage, and expressing his own favourable view. He mentioned a few matters still needed to complete it satisfactorily, and added:—

"The Canal must be regarded as a great work, more from its relation to the national and commercial interests of the world than from its engineering features. In this light it is impossible to over-estimate its importance. It will effect a total revolution in the mode of conducting the great traffic, the beneficial effects of which I believe it is difficult to realize. M. de Lesseps well deserves the respect he has created and the praises which have been bestowed. He has opened a channel of communication between the East and the West which will never again be closed."

The English Government, now, for the first time since Captain Spratt's unfavourable vaticinations, thought it worth while to obtain some trustworthy scientific information about the Canal. Mr. Hawkshaw's favourable Report seven years before had failed to convert them, and they now proceeded to make enquiries for themselves. The most proper department to undertake the new investigation was obviously the Admiralty; and on the 30th of December, 1869, they directed two very competent officers, namely Captain (now Admiral Sir George) Richards, R.N., F.R.S, the Hydrographer to the Admiralty, and Colonel (now Lt.-General Sir Andrew) Clarke, C.B., of the Royal Engineers, Director of Engineering and Architectural Works to the Admiralty, to undertake the enquiry.

Their commission was—

"To proceed to Egypt and to obtain on the spot the fullest information in their power as to the present condition of the Suez Canal and the works proposed to be carried out in connection with it, and to report to what extent the Canal may be expected to be available for the purposes of Her Majesty's Naval Service, including the Transport Service to and from the East."

The Commissioners reached Alexandria on the 28th of January, 1870, examined the whole works, and made their Report—a most valuable document, illustrated with many elaborate drawings—in the February following. The result of their observations is summed up in the following conclusions:—

"1. That for a certain class of vessels this great work, which must always be a monument of persevering energy and engineering skill, as it now stands is a convenient mode of passage from the Mediterranean to the Red Sea.

"2. That it will be so to a greater extent when the works contemplated, viz., the deepening of certain shallow parts, the enlargement of the *gares* (side refuges), and the widening and improvement of the curves, are carried out.

"3. That it is available for the transit of ships employed in the Eastern seas, with the exception of the large ironclads and other exceptionally heavy vessels.

"4. That for the present type of Indian transports it is not a desirable route.

"5. Further, we think that the cost of maintenance will not exceed the amount estimated for it when the work was first projected."

They then remark that, adverting to the prospects of the Canal as the grand marine highway from Europe to the East, the real drawback is its narrowness, the want of width alone preventing its being pronounced a complete success as a permanent navigable route for the largest ships from sea to sea. And they add that to increase the width would be a perfectly feasible undertaking, at a cost easily calculable.

This was no doubt a highly favourable Report, and tended to bring about the remarkable change in the attitude of the British Government towards the Canal, which was so strikingly manifested a few years later.

But even after the successful completion of his great Work, M. de Lesseps was not destined to be freed from care.

In 1871 came a financial difficulty with the Khedive as to the privileges of shareholders; and soon afterwards there arose a much more important dispute about the tonnage duties to be charged on vessels. This was of course a vital point, affecting the remuneration of the proprietors for their outlay, and it led to a long series of most complicated discussions with many European powers, often very acrimonious, which continued many years. The British Government was actively engaged in these, and a sort of Commission seems to have been appointed, which sat towards the end of 1873, the Government being represented by an officer of the Royal Engineers, Colonel Stokes, now General Sir John Stokes, K.C.B.

While this affair was still going on, another matter turned up which interested Great Britain much more nearly and directly. Some time before, there had been vague reports that, as the financial prospects of the Company were very unpromising, it might perhaps be possible for England, with her long purse, to give them some aid, and at the same time to acquire some rights over the management of the Canal. The Government was not indisposed to entertain the idea, and it determined, as a preliminary, to get as much information as possible, as to the

actual condition of the Canal. For this purpose, in January, 1874, Colonel Stokes was instructed, after his work on the Tonnage Commission was ended, to visit Egypt and make another Report on the subject. This he did at great length, and the information soon proved useful.

In April, 1874, it became known that the Khedive, who held 176,600 original shares in the Canal, wished to sell them, and Lord Derby (then Foreign Secretary under the Government of Mr. Disraeli), who saw at once that this would be a very easy way for England to acquire interest in the Canal, opened negotiations on the subject. In the course of them Colonel Stokes went again to Egypt, and finally the shares were bought for about £4,000,000, although the interest on them was mortgaged up to 1894. The purchase was ratified in 1876, the tonnage question being also settled at the same time. Although this purchase seemed merely a large commercial transaction, it was impossible to ignore its great political significance, as giving the English nation a large share in the control of the Canal; a work which had become the keystone of Mediterranean politics, and the gate of the road to the Eastern Empires of the world.

It is scarcely necessary to add that throughout all these various transactions, negotiations, and disputes, M. de Lesseps took the most active part in the Company's interests; and whatever branch of the work had to be dealt with, whether diplomacy, finance, engineering or internal management, he was always the life and soul of the business. It was not till the purchase of the shares had finally extinguished the animosity of his old enemy, the British Government, that he could be free from worry in regard to the affairs of the Canal. At the time of the British Expedition to Egypt in 1882 he was somewhat afraid lest it should be endangered by hostilities on its banks; but this was a false alarm, and he remained untroubled at the head of the undertaking till his death.

And it had brought him great honours. In November 1869 the French Emperor elevated him to the rank of Grand Cross of the Legion of Honour; and in the following year he received many decorations from foreign countries. In 1870 the Geographical Society of Paris awarded him the Empress's new prize of 10,000 francs, which he returned to aid one of their expeditions. On the 11th of July Queen Victoria created him an honorary Knight Grand Commander of the Star of India.

About the same period, when he visited England for a few weeks, he had many complimentary receptions. He was splendidly

feasted at the Mansion House, and presented with the freedom of the City in a casket of Egyptian device. On the 4th of July the Duke of Sutherland gave him a grand banquet at Stafford House, when several old opponents of the Canal were present, notably Mr. Disraeli; and on the 7th a magnificent festival, attended by some of the Royal Family, was got up in his honour at the Crystal Palace.

On the 11th of May, 1880, he was elected an Honorary Member of this Institution by the unanimous recommendation of Council:

"Because of his eminent services to engineering science and practice by the conception and successful prosecution, under many difficulties, of the design of uniting the Mediterranean Sea with the Red Sea by the Suez Canal—one of the grandest and most important public works of modern times."

But all former honours were thrown into the shade by his admission as one of the forty "Immortals" of the famous French Academy of Sciences. Into this select band he was elected in 1884 to fill the chair lately occupied by M. Henri Martin, the historian, and formerly by M. Thiers. On this event he was saluted by Gambetta with the name of *Le Grand Français*, a title he always retained even in his most mournful subsequent troubles. His reception on the 23rd of April was one of the red-letter days in the history of the Academy; for such a galaxy of celebrities had rarely gathered under the cupola of the Institute. The sponsors of the new member were Victor Hugo and Edouard Pailleron. M. Renan was in his place as Director. M. de Lesseps had to deliver an address of thanks for his election, which he did with great modesty, and M. Renan replied, in a discourse which was full of compliment to the hero, and which, it was said, had for eloquence never been excelled in the annals of the Academy.

When M. de Lesseps thus received the crowning honour of his life, he was in his 80th year. His long career had been chequered, he had had many severe trials to endure, many hard battles to fight; but in the pursuit of a high and worthy object his indomitable spirit and his splendid genius had carried him on in his victorious course till he had attained his noble purpose, and excited the admiration of the world. His sun was near the horizon, and to all human appearance it was setting in glory. It is sad to have to chronicle the almost incredible fact that the few remaining years of his life involved him in a shadow, continually darkening with deeper and deeper gloom, until his grey hairs were indeed "brought down with sorrow to the grave."

Alexander having conquered one world, sighed for more worlds

to conquer. M. de Lesseps having artificially joined two inland seas, longed to perform the greater feat of joining two wide oceans; and in an evil hour took up the idea of piercing the isthmus that separated the Atlantic from the Pacific. There was nothing unreasonable in this idea. He had by his energy and perseverance conquered the difficulties of the Isthmus of Suez, and why might he not also conquer those of the Isthmus of Panama?

Many different schemes had been proposed from time to time, most of which have been discussed before this Institution and will be found recorded in its Proceedings. In 1875 a conference had been held at Antwerp in which M. de Lesseps, from his experience in such matters, was placed in the chair; and such favourable auguries were drawn that a larger congress was called to meet at Paris in 1879. M. de Lesseps afterwards published a long article upon it,[1] and this appears to have been the time when he first earnestly took up the subject.

It is, for obvious reasons, unnecessary to go into details on this most painful occupation of his latest years; it must suffice to mention, as briefly as possible, some of its leading features; and these may conveniently be extracted from the summary of the history given in the *Times* the day after the death of M. de Lesseps, the 8th December, 1894.

The waterway designed by M. de Lesseps was intended to connect the Atlantic ocean at Aspinwall (or Colon) with the Pacific at the capital city of Panama, the oldest existing European settlement in the whole of America. His plan was to follow the course of the railway already connecting the two cities, except in certain places, where the line of the River Chagres was to be more closely adhered to. The whole length was only 54 miles, and the two chief difficulties lay in the floods of the river and in the excavation of a long ravine, about 350 feet deep, through the Cordilleras.

In February, 1881, he had formed his company and operations were begun; but for the next six years the work was only fitfully continued, and accounts were prevalent of the enormous expenses incurred, and the serious loss of life which the climate caused among the labourers. In December, 1888, the company suspended payment; great excitement prevailed, and the matter was taken up by Government and got into the Chambers.

In April, 1891, it was attempted to found a new company, but the feeling became very bitter when it was found that out of

[1] Translated in his "Recollections of Forty Years." Chapman and Hall, London, 1887.

enormous sums subscribed, large portions had been frittered away uselessly. An official enquiry followed, and in November, 1892, it was decided to take legal proceedings against the directors. But further investigations revealed gigantic scandals, implicating other persons, and of a nature which roused not only the Government but the whole country;—resulting in the overthrow of a ministry, the suspicious death of an eminent personage, and the disgrace of several great men who had previously stood high in public estimation.

A series of prosecutions followed, in which many persons were found guilty and punished, M. de Lesseps and his son being each sentenced to five years' imprisonment and the payment of a fine. The son suffered the punishment, but the father was spared the indignity, the sentence being merely communicated to his wife and concealed from her aged husband.

These sentences were considered very severe, and were thought to be dictated in some degree by political motives. The public anger was great, but few persons really believed that M. de Lesseps himself was guilty of anything more than a want of due regard for the practical difficulties, physical, economical and financial, of the Panama scheme generally.

During these humiliating proceedings he was living, aged and enfeebled, and almost insensible to what was going on around him, at his country-seat at La Chesnaye, where on that August morning in 1854 he suddenly heard of the event in Egypt which determined his life. He gradually sank away on the 7th of December, 1894, in his ninety-first year.

It will be refreshing to turn again in conclusion to the Suez Canal.

After the opening the traffic began to increase so much, that in ten or twelve years the question of greater accommodation had to be considered, and the work of deepening and widening was resolved on and gradually carried out. In 1890 the depth had been made 28 feet, and the width, in the portion from Port Saïd to the Bitter Lakes, was increased to 144 feet, and from them to Suez to 213 feet. The average time of passing in 1886 was thirty-six hours; in 1890 it was reduced to twenty-four hours.

The result has been a continual increase of both the number and the tonnage of the vessels. In the year 1870, 486 vessels passed through, having a tonnage of 655,000 tons. In 1890 the number was increased to 3,389 vessels with a tonnage of nearly 10,000,000 tons; and out of these, about three-fourths were British!

The total expenditure on the Canal is not easy to ascertain, but it is said that it amounted to about £20,000,000, and that the profits divided in 1890 were about a million and a half sterling, over and above 5 per cent. interest on the outlay.[1]

Surely, with these facts on record, it behoves the British nation (as has been already well remarked) to continue to speak with honour, admiration, gratitude, and deep regret, of the illustrious deceased. They can well afford to brush aside the unhappy Panama episode, and to let the reputation of *Le Grand Français* rest on the work that was always dearest to his heart, the Suez Canal.

JOSEPH HENRY BRADY, son of Mr. Francis Brady, Chief Engineer of the South Eastern Railway Company, was born on the 6th of November, 1851. After leaving school, he served a pupilage of five years to his father, during which time he was employed in the ordinary routine duties of an engineer's office and on the construction of the Greenwich and Woolwich Railway. He then, from 1872 to 1874, had charge, as Resident Engineer, of the construction of the Hythe and Sandgate branch line, and of the laying out of the Seabrook Estate near the latter town.

In October, 1874, Mr. Brady proceeded to South Africa to join the staff of the Cape Government Railways. For the first two years he was engaged as an Assistant Engineer on survey work, and was then appointed Acting District Engineer on the construction staff under the late Mr. Henry J. Pauling.[2] In May, 1877, he was placed in charge of a length of 25 miles, which was subsequently increased to 50 miles, and in July of the following year he was entrusted with the maintenance of the line beyond Worcester. He gradually took over the whole length of 230 miles, between Worcester and Beaufort West, and became responsible for the completion of the construction work of the several districts, including the erection of four important iron bridges. In February, 1882, he was transferred from Section 2 to Section 1 of the open lines on the Western System (246 miles), and was placed in charge of extensive additions to the locomotive shops at Salt River. He was appointed Acting Maintenance Engineer of the Western System in May, 1884. At the end of that year, however, he resigned the service.

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[1] Chambers' "Encyclopædia," 1892, article *Suez Canal.*

[2] Minutes of Proceedings Inst. C.E., vol. cxii. p. 359.

In the spring of 1885 Mr. Brady obtained the post of Colonial Engineer and Sanitary Inspector in Gambia, where he remained for five years. During that time he acted twice as Treasurer and Collector of Customs for the colony, and also served as a Justice of the Peace and a Member of the Legislative Council. In 1890 he was appointed Superintendent of Public Works in the island of Barbados. The principal work upon which he was occupied in that capacity was a scheme for improving the harbour of Bridgetown. While engaged in the performance of his duties Mr. Brady was unfortunately attacked by sunstroke, which resulted in death on the 24th of July, 1894. He was elected a Member of the Institution on the 5th of May, 1885.

JAMES CROSS was born at Uddingston, near Glasgow, on the 22nd of February, 1829. He was trained for the profession under the late Mr. Alexander Adie, and in 1854 was appointed Engineer to the St. Helen's Canal and Railway Company. That post he held for ten years, when the undertaking was purchased by the London and North Western Railway Company. In 1865 Mr. Cross became managing trustee and superintendent of the estate of the late Mr. John Hutchinson—one of the founders of Widnes—which consisted of the West Bank Dock, a considerable extent of land, and important chemical works. With those undertakings he remained connected until his death.

Mr. Cross took great interest in all matters relating to the welfare of Widnes, and was for many years a member of the Local Board, serving the office of Chairman from 1875 to 1882. He was also at one time Chairman of the Highway Committee and Vice-Chairman of the School Board. Mr. Cross was an enthusiastic volunteer and was the possessor of the decoration given to officers of over twenty years' standing. On retiring from active service he was permitted to retain the rank of major and to wear the uniform of the corps, the 2nd South Lancashire. In 1881 he removed to North Wales, and was shortly afterwards appointed a Justice of the Peace for the County of Denbighshire.

Mr. Cross died at his residence in Llangollen on the 13th of October, 1894, after some months of failing health. He was elected a Member of the Institution on the 5th of December, 1865.

HENRY FAIJA was born in London on the 14th of November, 1844, and was educated at University College School. In March, 1860, he was articled to Messrs. Westwood, Baillie and Campbell, of London Yard, Isle of Dogs, in whose shops and drawing-office he gained some experience of engineering and shipbuilding. On the expiration of his articles he served as an improver with Messrs. Martin Samuelson and Company, shipbuilders, of Hull, and in 1866 was appointed chief draughtsman and sub-manager to Messrs. Bainbridge, Davy and Hopper, of Willington Quay, Newcastle-on-Tyne. While in the employment of that firm he designed and superintended the construction of several first-class steamships. Leaving Messrs. Bainbridge and Co. in 1868, he became managing partner of the Railway Foundry Company at Stoke-on-Trent, in which capacity he was engaged in the construction of several bridges and other works for the North Staffordshire and the Market Drayton Railways, and in the manufacture of pumps and other machinery for the neighbouring iron and coal mines.

In 1871 Mr. Faija removed to London and took an office in John Street, Bedford Row, where he practised on his own account as an engineer. It was there that he, almost accidentally, took up the subject of Portland cement—on which he later became an authority—for, on obtaining a commission to design and erect a cement works, he was so impressed with the crude and wasteful methods then employed for the production of that material, that he determined to devote special attention to the mechanical and chemical examination of cement, lime and concrete, and to their behaviour under the varying conditions met with in practice. About the year 1875 he removed to Westminster, where he established a Portland Cement Testing-room and Laboratory. There he examined and reported upon cements and kindred materials, and the extent which this branch of his practice ultimately reached may be taken as indicative of the value attached to his opinion on such matters. In 1881 he presented to the Institution a Paper entitled "Results of Experiments with Portland Cement gauged with Sea and Fresh Water under different conditions,"[1] and two years later a second Paper—"On the Mechanical Examination and Testing of Portland Cement."[2] He also contributed essays on this subject to the Institution of Mechanical Engineers,[3] to the Royal Institute of British Archi-

[1] Minutes of Proceedings Inst. C.E., vol. lxvii. p. 349.
[2] *Ibid*, vol. lxxv. p. 213.
[3] Proceedings Inst. Mech. Engs., 1875, p. 46.

tects,[1] to the British Association,[2] to the Society of Engineers,[3] and to the International Engineering Congress held at Chicago in connection with the Columbian Exposition of 1893.[4] In 1881 he published a book entitled "Portland Cement for Users," which met with considerable success, and from time to time he contributed articles to the leading technical journals.

Mr. Faija displayed much ability as an inventor. As an outcome of his researches as to the constructive value of cement he devised an apparatus for determining its freedom from subsequent expansion. By artificially accelerating the setting and hardening of a sample this process enables an opinion to be formed in twenty-four hours, which in the ordinary course it would take at least a week to arrive at. He also invented a briquette-testing machine, and an apparatus for mixing powdered substances which is largely used by manufacturing chemists and in the testing-rooms of cement makers. At the time of the failures at Aberdeen Harbour he was particularly active in opposing the idea that the magnesia precipitated from sea-water had an injurious effect on concrete properly constructed of sound cement.[5]

Mr. Faija's useful career was prematurely cut short by a complaint of the throat. After a protracted and distressing illness, which for three months compelled him to retire from active work, he died at Sunbury-on-Thames on the 21st of August, 1894, at the early age of forty-nine. As an engineer Mr. Faija was principally occupied in the design and in superintending the construction of works, plant and machinery for the manufacture of cement and of building materials generally. As a man his unvarying straightforwardness and upright dealing were highly appreciated, while his kindly good nature and readiness to promote the enjoyment of others made him everywhere popular. On the Thames, where most of his spare time was spent, he was well known as an amateur punter, and he frequently acted as judge or umpire at the regattas held at Sunbury, to the success of which his tact and good temper contributed not a little. Mr. Faija was elected an Associate of the Institution on the 12th of January, 1875, was subsequently placed among the Associate Members, and was transferred to the class of Member on the 20th of May, 1884.

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[1] R. I. B. A. Trans., 1879–80, p. 109; Journal of Proceedings, 1888, p. 175.

[2] Report British Association for the Advancement of Science, 1891, p. 764.

[3] Trans. Society Engineers, 1885, p. 95; 1888, p. 89; 1889, p. 107.

[4] Trans. Am. Soc. C.E., Int. Eng. Congress, 1893, Part II. p. 43.

[5] Minutes of Proceedings Inst. C.E., vol. cvii. p. 117.

THOMAS MASTERMAN HARDY JOHNSTON, born at Belfast on the 23rd of July, 1817, was the youngest son of the late Captain E. Johnston, R.N., and godson of the late Admiral Sir Thomas Masterman Hardy, Bart., G.C.B., Captain of the "Victory" (Lord Nelson's flagship) at the Battle of Trafalgar. He received his early education at Chelsea, and subsequently in France. On leaving school he was appointed to the Ordnance Trigonometrical Survey of England, and was engaged in surveys throughout portions of Nottinghamshire, Yorkshire, Lancashire and Cheshire. He then served a short pupilage under the late Mr. John Barrow, Civil Engineer, of Chester, during which he was principally occupied in making surveys and plans of several parishes in North Wales under the Tithes Commutation Act.

In 1843–44 Mr. Johnston served as Assistant Engineer under Mr. Robert Stephenson,[1] on the permanent surveys of 40 miles of the Chester and Holyhead Railway from Chester to Conway. He was subsequently engaged till 1847 under Mr. Joseph Locke,[2] upon the parliamentary surveys of the Caledonian Extension and the Central Devon and Cornwall Railways. From 1847 to 1856 he served under Mr. I. K. Brunel,[3] on the works of the South Devon, Cornwall, and West Cornwall Railways, including those of the Great Western Docks at Plymouth. He was also engaged on the survey for the site of the Royal Albert Bridge over the River Tamar at Saltash, and on the operations connected with the foundations of the centre pier, laid at a depth of 90 feet below high water and in a tide-way running at the rate of 7 miles an hour.[4] In July, 1850, he was employed by Mr. James Meadows Rendel[5] to survey and make a chart of the harbour and roadstead of St. Peter in the island of Guernsey, together with detailed sections, soundings, borings, &c., for a proposed harbour.

In March, 1856, Mr. Johnston was appointed an Assistant Engineer on the staff of the Madras Railway Company, and was placed in charge of 25 miles on the South-West line, and subsequently as Resident Engineer at Cuddapah of 75 miles of the North West line. While on those works, he had an attack of rheumatic fever which obliged him to take sick-leave. Returning to India in April, 1862, Mr. Johnston was again posted to his old quarters at Cuddapah, where he was engaged till the beginning of April, 1865, when he again went home

[1] Minutes of Proceedings Inst. C.E., vol. xix. p. 176.
[2] *Ibid*, vol. xx. p. 141.
[3] *Ibid*, vol. xix. p. 169.
[4] *Ibid*, vol. xxi. p. 268.
[5] *Ibid*, vol. xvi. p. 133.

on leave for three months. In the following autumn he was transferred to an unhealthy district, where he suffered much from fever and rheumatism. In May, 1867, his engagement with the Madras Railway Company terminated. During the eleven years of his service many large bridges and other important works, extending over an aggregate length of 100 miles, were completed under his supervision.

Mr. Johnston was then appointed Acting Chief Engineer to the Government of Travancore, and was actively engaged for two years in re-organizing the Public Works Department of that State. In October, 1869, he became an Executive Engineer on the Indus Valley State Railway, and was placed in charge of the Empress Bridge Division over the River Sutlej. The prospect of being connected with the construction of so important a work as the great bridge over the Sutlej[1] was, however, of but short duration, for on the 25th of January, 1870, he was appointed by Sir Salar Jung—then Prime Minister of Hyderabad—Secretary and Consulting Engineer in the Public Works Department of the Nizam's Government. In those capacities, he was engaged in organizing and conducting the administration of a department extending over an area of nearly 100,000 square miles, with a population of 10,000,000 until September, 1872. The Chanda coal-fields, in the north-east of the dominion near Nagpur, were developed, and a railway from Hyderabad to Masulipatam was projected and surveyed by him. He also had a trigonometrical survey and map made of the city of Hyderabad and its environs, with a view of carrying out an efficient water-supply, drainage, and other sanitary improvements. Workshops, furnished with modern English tools, under the management of a skilled English mechanic, were also established at Chudderghaut near the city.

In September, 1872, finding that his health had seriously suffered from so long a residence in India, Mr. Johnston returned to England. In the following July he emigrated with his family to New Zealand. He arrived in Auckland in October, 1873, since which he lived a comparatively retired life. After some years of failing health he expired at his residence in Christchurch on the 24th of September, 1894. Mr. Johnston married on the 15th of June, 1865, the fourth daughter of the late Rev. Albany Wade, of Hilton Castle, County Durham, by whom he leaves five daughters and three sons. He was elected a Member of the Institution on the 7th of February, 1860.

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[1] Minutes of Proceedings Inst. C.E., vol. lxv. p. 242.

WILLIAM RICHARD LE FANU, second son of the Very Rev. Thomas Philip Le Fanu, LL.D., Dean of Emly and Rector of Abington, in the county of Limerick, was born on the 24th of February, 1816, at the Royal Hibernian Military School, Dublin, to which institution Dr. Le Fanu was then Chaplain. The eldest son was the well-known novelist, Joseph Sheridan Le Fanu.

The subject of this notice was educated at home, and afterwards entered Trinity College, Dublin, graduating as B.A. of the University in 1839. He then became a pupil of Mr. (afterwards Sir) John MacNeill,[1] under whom he was engaged on extensive sea-reclamations, harbours, and other works. With the development of the railway system Mr. Le Fanu's work took principally that direction. Sir John MacNeill was Engineer-in-Chief of most of the principal railways first constructed in Ireland: the Dublin and Drogheda, opened in 1844; the Dublin and Cashel, opened first to Carlow in 1846, then to Thurles in 1848, and finally completed to Cork under its present name of the Great Southern and Western Railway. During those years Mr. Le Fanu and Mr. Matthew Blakiston were Sir John MacNeill's principal assistants, the former having charge of all the Parliamentary and other work south of Dublin. In 1846 he acted as Resident Engineer in charge of the completion of the Cork terminal section of the Great Southern and Western Railway, and went to live at Rathpeacon House, near Cork.

On the termination of Sir John MacNeill's connection with the Great Southern and Western Railway, Mr. Le Fanu became the Consulting Engineer to that Company, and under his advice and superintendence the branches and extensions to Killarney (and afterwards to Tralee), to Tullamore (and afterwards to Athlone), to Roscrea (and afterwards to Parsonstown and Nenagh), and from Mallow to Fermoy, were carried out. He also designed and carried out railways for other companies: the Limerick and Foynes line; the Bagnalstown and Ballywilliam; and the Dublin, Wicklow and Wexford Railway from Wicklow to Wexford. He was Consulting Engineer of the Cork and Bandon Railway Company, and in 1856 designed the extensions of that line, which were not then sanctioned by Parliament, but have since been carried out. In 1861 he also became Consulting Engineer to the Board which had charge of the lighthouses round the coast of Ireland, then called the "Ballast Board," but now known as the "Board of Irish Lights." During the short time he was

[1] Minutes of Proceedings Inst. C.E., vol. lxxiii. p. 361.

adviser to this Board no lighthouse work of any special character engaged his attention.

In July, 1863, Mr. Le Fanu accepted the position of Commissioner of Public Works, then vacant by the retirement of Sir Richard Griffith, Bart.[1] The change from active professional work, with the uncertainties, not in themselves uninteresting, with which the result of new projects are attended, was not at first much to Mr. Le Fanu's taste; and he hesitated to give up the freedom of private practice, with its more remunerative prizes, for the harness of a high Government official. Friends, however, strongly pressed him, and he became Second Commissioner, Colonel Sir John McKerlie, K.C.B., becoming the Chairman of the Board. From the time he assumed these duties he devoted himself wholly and thoroughly to the work of the department.

The Board of Works for Ireland has entrusted to it business of a much wider nature than is indicated by the title of the department. Besides the charge of all Government and public buildings, it takes, in Ireland, the place of the Public Works Loan Commissioners, and to some extent that of the Inclosure Commissioners, in England. The Board is also charged with the maintenance of Inland Navigations, and the Commissioners are likewise members of the Board of Control for Lunatic Asylums, and Commissioners in charge of the harbours of Kingstown and Howth.

It was therefore no sinecure to which Mr. Le Fanu succeeded when he became a Commissioner of Public Works. All applications for Government loans for public works, landed property improvement, drainage of lands, erection of farmsteads, scutch-mills, planting, improvement in navigation and water-power, came under his control. He had also to hold all meetings for making awards under the Arterial Drainage Acts for assessing charges for improvements, and to advise as to all matters in connection with inland navigation, harbours and piers, fisheries, and post roads, which came under the control of the Board. All loans, sanctioned by the Local Government Board, which sanitary authorities sought to borrow from the Treasury, came under his supervision. Except during his annual holiday or on inspections he was hardly ever a day absent from the Office of Public Works, and by making a rule of never allowing arrears to accumulate, he got through a vast amount of steady work year by year.

As a railway engineer Mr. Le Fanu carried out many large and important works, though none were of such novel or striking

[1] Minutes of Proceedings Inst. C.E., vol. lv. p. 317.

importance as to call for special description. It is authoritatively stated that, so carefully were estimates prepared by him, that in no case was the amount exceeded which he advised as the capital to be provided. He was a well-known figure in the Committee Rooms while in private practice, no session passing without his having Bills to support or oppose. He was retired from the post of Commissioner of Public Works in 1890, under the age regulation then for the first time applied to the whole Civil Service. In 1893 he published his well-known memoirs entitled "Seventy Years of Irish Life."

Mr. Le Fanu died on the 8th of September, 1894, at his residence, Summerhill, Enniskerry, Co. Wicklow, in the seventy-ninth year of his age. He was elected a Member of the Institution on the 24th of May, 1853.

JAMES BRADDON McCALLUM was born on the 18th of June, 1852, at East Stonehouse, Devon, and was educated at private schools in Plymouth. In July, 1867, he was articled for three years to Mr. Robert Hodge, then Surveyor and Water Engineer to the borough of Plymouth, and remained with that gentleman as an assistant until May, 1871. During that time he superintended —in addition to ordinary routine duties—the construction of the sewage outfall works at the Great Western Docks. Mr. McCallum then acted for nearly twelve months as Assistant Surveyor to the borough of Reigate, in which capacity he was engaged on main-drainage works and on the sewage farm at Earlswood. From 1872 to 1874 he was Chief Assistant to the Borough and Water Engineer of Reading, and from 1874 to 1876 he was a general assistant under Mr. George F. Deacon, then Borough and Water Engineer to the corporation of Liverpool. During the illness of the Surveyor to the Toxteth Park Local Board in 1876, Mr. McCallum acted in his place.

In November, 1876, when not much more than twenty-four years of age, Mr. McCallum was appointed Borough Surveyor of Stafford. During the six years he held that post he carried out important flood-prevention works, and designed and erected two bridges over the River Sow. He also designed a scheme for the sewerage and sewage-disposal of the town; reported upon and took the initial steps to obtain a new water-supply; and a Free Library and Museum, and a Sanitary Depôt for the disposal of the town-refuse, were erected from his designs.

Mr. McCallum's next appointment—in June, 1882—was that of Borough Engineer of Blackburn, to which was added in July, 1884, the charge of the corporation waterworks. During the twelve years of his connection with that borough, he designed and carried out numerous public works, among which may be mentioned the Salford Bridge improvement, main sewerage works, public abattoirs, water-works extensions, a bridge over the river at Ewood, the new Queen's Park and Lake, public baths, and a refuse-destructor, costing together over £100,000. He also carried out 30 miles of street paving and other road works to the extent of about £250,000; 12 miles of tramways at a cost of £50,000; a fever hospital (£22,000) and an Art Gallery. At the time of his death he was engaged on sewage purification works, the estimate for which was upwards of £100,000.

Mr. McCallum died on the 30th of October, 1894, from the results of an accident. While crossing the road in front of his residence, on the 8th of that month, his foot slipped on a tram-rail and he fell, breaking a leg and dislocating an ankle. The bone was at once set, but various complications arose, which, in spite of every care and attention, proved fatal. Mr. McCallum was a Fellow of the Surveyors' Institution and a Member of Council of the Incorporated Association of Municipal and County Engineers. To the latter he presented, in 1885, "Some Particulars of the Municipal and Sanitary Works of Blackburn,"[1] while at the annual meeting of the Sanitary Institute, in 1878, he read a communication entitled "Sanitary Defects of Old Towns and Suggested Remedies."[2] He invented various sanitary appliances, obtaining a silver medal for a waste-water preventer at the International Health Exhibition of 1884. As a man he was kind-hearted and generous, always ready to render assistance to others to the utmost of his power. He married in 1882 Miss Alice Grace Marson, of Stafford, by whom he leaves two children. Mr. McCallum was elected an Associate Member of the Institution on the 1st of May, 1883, and was transferred to the class of Member on the 8th of November, 1887.

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[1] Proceedings Assoc. Municipal and Sanitary Engineers and Surveyors, vol. xii. p. 9.

[2] *The Sanitary Register*, October, 1878.

ALLAN DUNCAN STEWART, born on the 7th of March, 1831, was educated at the University of Cambridge, where he graduated 9th Wrangler in 1853. From 1855 to 1858 he served articles to Mr. Benjamin Hall Blyth,[1] and in 1859 and 1860 acted as Resident Engineer on the construction of the Banffshire Railway, and of a section of the Portpatrick line.

In 1861 Mr. Stewart began to practise in Edinburgh as a Civil Engineer. During the following twenty years he prepared Parliamentary plans for, and laid out—sometimes on his own responsibility and sometimes for other engineers—various lines of railway, including the Ascot and Aldershot, and the Sheffield, Buxton and Chapel-en-le-Frith. He also designed and superintended the construction of several bridges, among which may be mentioned that over the Tay at Grandtully; and works for the water-supply of the village of Liberton, for the drainage of Gorebridge, and for the widening and deepening of the rivers Leet and Tummel. Mr. Stewart was extensively employed in assisting Sir Thomas Bouch[2] in the design and execution of several iron and steel bridges, and in the various calculations involved, his high mathematical attainments and practical experience in iron construction being extremely useful. For Sir Thomas Bouch he prepared working drawings for the superstructure of the Redheugh Bridge, near Newcastle-on-Tyne; for the whole of the girders of the Tay Bridge; for the roofs of Waverley Station, Edinburgh, and Dundee Station; and for the steel piers, chains and girders of the proposed suspension bridge across the Firth of Forth. In 1880 he gave important evidence before the Royal Commission on the Tay Bridge disaster.[3]

From 1881 to 1890 Mr. Stewart acted as Chief Assistant Engineer for Sir John Fowler and Sir Benjamin Baker, on the design and construction of the Forth Bridge. He then practised in Westminster and obtained—in conjunction with Mr. J. M. Maclaren and Mr. W. Dunn—the first prize, of 500 guineas, in the competition designs for the Wembley Tower.[4] This design was not adopted, but Sir Benjamin Baker, being subsequently instructed to proceed with the work on a simpler and cheaper plan, associated Mr. Stewart with himself as joint Engineer. He was engaged in the duties connected with this office when

[1] Minutes of Proceedings Inst. C.E., vol. xxvi. p. 556.

[2] *Ibid*, vol. lxiii. p. 301.

[3] The Report and Minutes of Evidence may be found in the Library of the Institution.

[4] Library Inst. C.E., Tracts 8vo. vol. 493.

he was incapacitated by illness, which terminated fatally on the 31st of October, 1894, his decease being probably accelerated by the death of his son and daughter on the same day in his house a few weeks previously.

Mr. Stewart was elected a Member of the Institution on the 7th of February, 1882. Ten years later, he presented a valuable Paper on "Stresses and Deflections in Braced Girders,"[1] for which the Council awarded him a Telford Premium. He was of a retiring disposition, and rarely attended the meetings of the Institution; but those of his professional brethren who knew him best most regret his loss.

JOHN LEWIS FELIX TARGET was born in Paris on the 24th of June, 1829, and was educated in London. From 1848 to 1852 he worked under his father, who practised as a Civil Engineer in Mauritius, and was chiefly employed in erecting plant for the manufacture of sugar. In 1853, after passing the necessary examinations, Mr. Target became sworn Surveyor for the island of Mauritius, in which capacity he practised for several years. He obtained the prize offered by the municipality of Port Louis for the best design for the water-supply of that town. In 1856 he became a naturalised Englishman. From 1865 to 1868 he was employed as Crown Surveyor to the Mauritius Railways, and in the latter year he acted for several months as engineer to the General Board of Health of the island. The next four years he spent partly in France and partly in England, engaged on various matters relating to sanitary engineering.

In May, 1873, Mr. Target was appointed a District Engineer in the Public Works Department of Jamaica, and for some months had charge of the Western division of the island. In February of the following year he became Executive Engineer to the Kingston and Lignanea Waterworks, which post he held until his retirement from the Public Service of Jamaica in April, 1885. During that period he carried to completion the new works for the supply of Kingston designed by his predecessor, the late Mr. T. S. Farrar. These works comprised a settling-reservoir, two filter-beds and a pure-water tank capable of supplying 1½ million gallons per annum, and while in charge of them Mr. Target carried out a

[1] Minutes of Proceedings Inst. C.E., vol. cix. p. 269.

series of experiments on the heights of jets, the results of which were embodied in a Paper presented by him to the Institution.[1]

In February, 1884, Mr. Target was commissioned by the then Governor of Jamaica, Sir Henry Norman, to report on the progress of the works of the Panama Canal, and especially as to the condition of the Jamaica labourers employed thereon. For that service, which his French extraction enabled him to perform the more efficiently, he received the thanks of the Governor. On his retirement from the Public Service, Mr. Target acted for three years as Consulting Engineer to the Anglo-Dutch contractors for a portion of the works of the Panama Canal. His visits to that unhealthy climate, however, aggravated the malady—gout—from which he was a great sufferer, and he was forced to resign the appointment.

Thereafter Mr. Target practically abandoned the active pursuit of the profession. The last years of his life were spent partly in London and partly at Southsea. Repeated attacks of gout had affected his heart, and he died suddenly at the latter place on the 22nd of September, 1894. Though of a somewhat hasty and impatient temperament, Mr. Target endeared himself to those who knew him best by his honesty of purpose. He was elected an Associate of the Institution on the 6th of May, 1873, was subsequently placed among the Associate Members, and was transferred to the class of Member on the 23rd of March, 1880. In addition to the Paper already referred to, he presented to the Institution the following Original Communications:—"On the Main Drainage of Paris, and the Utilization of its Sewage,"[2] for which he was awarded a Telford Premium; and "Experiments on a New Form of Module for Irrigation Purposes."[3]

WILLIAM HENRY BRACE, born on the 29th of November, 1857, obtained his engineering training in the office of Mr. Alfred Brace Cruse,[4] who for many years was engaged on irrigation works in India and in Ceylon. From 1879 to 1883 he was occupied in India on the construction of sluices and bridges, on the survey of roads, and on the preparation of village allotments. In June, 1883, he was appointed a draughtsman in

[1] Minutes of Proceedings Inst. C.E., vol. liv. p. 276.
[2] *Ibid*, vol. liii. p. 193. [3] *Ibid*, vol. lxv. p. 313.
[4] *Ibid*, vol. lxxxii. p. 383.

the Public Works Department of Selangor, and in the following December was promoted to the office of Clerk of Works. Two years later he was placed in charge of the Klang and Coast Districts, of which he was appointed District Superintendent in January, 1887, under Mr. Henry Franklin Bellamy. His duties comprised the construction of roads of every description and the erection of public buildings, lighthouses, bridges, piers and jetties.

Mr. Brace left the service of the Public Works Department of Selangor in 1890, and was then engaged, for the contractor, Mr. G. D. Gordon, on the construction of the section from Teluk-Anson to Tapak of the Kinta Valley Railway, in the adjoining protected native State of Perak. There he died early in 1892. While in the protected native States Mr. Brace had the reputation of being an active, good all-round man, experienced in that peculiar description of practical work which is essential to an engineer in the colonies, and only to be acquired by actual residence. He was elected an Associate Member of the Institution on the 14th of January, 1890.

JOHN WILLIAMS BREWER, born at Llanelly, Brecknockshire, on the 26th of March, 1841, was the fourth son of the late Mr. John Brewer, who for more than forty years was engineer and agent to an important firm of iron manufacturers, and was also manager of the Rumney Railway previous to its amalgamation with the Brecon and Merthyr line. Leaving school at the age of fifteen, he spent three years in the Locomotive Department of the Rumney Railway, under his father, and then served articles for a similar period to Mr. David Jones, the engineer of that line. After the expiration of his pupilage he made surveys and prepared working drawings for the conversion of the railway from Bassaleg to Rhymney into a parliamentary line and for the branch from Machen to Caerphilly.

In June, 1861, Mr. Brewer was appointed an Assistant to Mr. John Williams,[1] the engineer of new works on the Taff Vale Railway, and for the following nine years was engaged on the Llantrisant and Taff Vale Junction, the Dare Valley, the Brecon and Merthyr, and the Rumney lines; on the Pontypridd Waterworks; and on the Llangennech and other colliery surveys.

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[1] Minutes of Proceedings Inst. C.E., vol. xcii. p. 393.

In 1870 he took an office in Cardiff, where he practised for the next ten years as a Civil and Mining Engineer. During that period he constructed branch lines to the Treforest Tinworks, to the Rhondda and Ely Colliery, and to the Penrhiwceiber Colliery; prepared surveys of the Ynysybwl branch, of the Penarth Docks, of several collieries and of Mr. Crawshay Bailey's mineral estates; and assisted in the general engineering work of the Taff Vale Railway.

From 1880 until his death Mr. Brewer was permanently in the service of the Taff Vale Railway, being engaged at first principally in surveys of the underground workings of the collieries under and in the vicinity of the Company's property. In 1882 he prepared the contract surveys, sections and bridge drawings for, and had sole charge of, the construction of the Treferig Valley line, and in the following year he was engaged in the Treforest to Pontypridd widening works and on the Penarth Extension. In 1884 and 1885 he made surveys and prepared parliamentary plans and contract drawings for the Roath Branch, and for the Cardiff, Penarth and Barry Junction Railway. On the death of Mr. John Williams in 1887, Mr. Brewer was appointed Surveyor and Assistant Engineer to the Company, under Mr. H. O. Fisher, and, on the retirement of that gentleman in 1891, he succeeded to the post of Chief Engineer. He then prepared parliamentary plans for the Cowbridge and Aberthaw Railway, which, in conjunction with Mr. H. O. Fisher, he subsequently constructed. He also completed the Penywal branch line for the Great Western Colliery Company, and in 1890 he revised the whole of the rentals of the Taff Vale Railway Company.

Mr. Brewer died on the 26th of August, 1894, from an internal complaint, at the comparatively early age of fifty-three. As an engineer he possessed marked ability, as was evidenced by the position to which he attained in the service of the Taff Vale Railway Company. He was a keen sportsman and in his younger days was well known as an athlete. In 1878 he married the eldest sister of Sir Morgan Morgan of Cardiff. Mr. Brewer was elected an Associate Member of the Institution on the 12th of May, 1891.

WILLIAM JOSEPH BROWN, born in London on the 24th of April, 1835, commenced his business career in a solicitor's office, where he obtained a good elementary knowledge of legal matters. A desire for foreign travel, however, induced him to proceed to

Bermuda in a clerical capacity on board H.M.S. "Chatham." On his return he was again for a time in a lawyer's office, but in 1853 he obtained an appointment in the well-known engineering firm of Messrs. James Simpson and Company, whose works were then in the Belgrave Road, Pimlico.

From the position of a junior clerk, Mr. Brown rose to that of cashier, and ultimately became secretary and managing director of the Company, his connection with which lasted for more than forty years. His financial abilities were of a high order, and he possessed a keen aptitude for business. His success was probably much facilitated by his unvarying geniality and frank disposition. For three years prior to his death, which took place on the 4th of December, 1894, Mr. Brown had been afflicted by almost total loss of sight. This he bore with exemplary fortitude, as well as other ailments culminating in acute inflammation of the kidneys, coupled with cardiac syncope, to which he succumbed.

Mr. Brown was married on the 11th of September, 1862, to his cousin, Miss Elizabeth Rowell, whom he leaves a widow with four daughters. He was elected an Associate of the Institution on the 2nd of February, 1875, and was subsequently placed in the class of Associate Member.

JOHN BURGESS was born at Furness Vale, near Stockport, on the 29th of September, 1825. In 1846 he entered the Gasworks Department of the Corporation of Manchester, where he remained ten years, acting during a considerable portion of that time as assistant manager of the Gaythorn station. In 1856 he was appointed engineer and manager to the Huddersfield Gas Company, his services being retained on the purchase of the works by the Corporation sixteen years later.

When Mr. Burgess entered upon his duties at Huddersfield the works were small, having a storage capacity of about 400,000 cubic feet only. From his designs there have since been erected four new gasholders, the latest of which has a capacity of 1,100,000 cubic feet, the total capacity being about 3,600,000 cubic feet. Other additions were a large retort-house of modern design, fitted with regenerative furnaces and adapted for the application of the latest labour-saving machinery; a purifying house with hoisting machinery and a hydraulic travelling-crane; a new engine-house; new scrubbers of modern design; a large plant for continuously producing sulphate of ammonia from the

residual ammoniacal liquor; and a new station meter, with house and testing-laboratory. He was also actively engaged in connection with the laying down of plant for lighting the town by electricity—a work which was undertaken by the Corporation. On the 2nd of March, 1892, Mr. Burgess was compelled by a second attack of paralysis to retire from the service of the Corporation, with the position of consulting engineer. From that time he was confined to the house, and a third attack proved fatal on the 6th of July, 1894.

As an engineer Mr. Burgess was hardworking, painstaking and conscientious, and under his management the Huddersfield Gasworks yielded a large profit, which was devoted to the reduction of the rates. For many years he acted as treasurer of the Huddersfield Literary and Scientific Society, and as an officer of the Mechanics' Institute. He also took a warm interest in the Technical School, serving as a governor from 1886 to 1893, and was a Past Master of the local lodge of Freemasons. Mr. Burgess was elected an Associate of the Institution on the 4th of May, 1875, and was subsequently placed in the class of Associate Member.

GEORGE HANNYNGTON COLE-BAKER, B.A., eldest son of the late Mr. George Cole-Baker of Ballydavid, co. Tipperary, was born at that place on the 12th of January, 1866. He was educated in the Isle of Man and at the University of Cambridge, where he graduated in 1887 with honours in mathematics, and was twice coxswain of the winning crew in the inter-University boat race.

After taking his degree Mr. Cole-Baker served a pupilage of three years to Mr. J. C. Park in the works of the North London Railway Company at Bow. During that time he gained considerable knowledge of the construction and repair of locomotives and passed through the various shops in a satisfactory manner. In 1891 he was appointed by Mr. Kennett Bayley an Assistant Engineer on the construction of the Valencia branch of the Great Southern and Western Railway of Ireland, and was engaged on the staff until the completion of that line.

On the 9th of September, 1894, Mr. Cole-Baker went for a sail at Rossbeigh, co. Kerry, in a small peculiarly-fashioned boat devised and constructed by himself—a flat-bottomed duck-punt, about 15 feet long, having a sail but unprovided with paddles.

It is not known exactly how he was lost, as, although a high sea was running at the time, he had often been out in this boat in much rougher weather. At one o'clock on the following morning his body was found cast on the shore. A bright and genial, yet independent manner, and a character sympathetic yet firm, made him universally popular, and enabled him to gain in a remarkable degree the confidence and affection of the workmen and peasantry with whom he came in contact. He leaves a widow and a son of eight months old. Mr. Cole-Baker was elected an Associate Member of the Institution on the 2nd of February, 1892.

JAMES FRENCH, second son of Mr. William French, Surveyor, was born on the 19th of May, 1846, at John Street, Bedford Row, London. In 1863 he was articled to Messrs. Lucas Brothers for three years, during which time he went through the shops and the machinery department of that firm at Lowestoft. From 1866 to 1872 he was employed by Messrs. Lucas Brothers as an assistant on various contracts, including the stations on the metropolitan extension of the London, Chatham and Dover Railway, the Albert Hall and the Exhibition buildings at South Kensington. For the two following years he assisted his father in taking out quantities, chiefly in connection with the metropolitan extensions of the Great Eastern Railway.

In 1874 Mr. French was appointed Chief Assistant to Mr. J. C. Simpson on the construction of the Main Drainage works of Buenos Ayres. During the three years he was thus engaged, he was responsible for the carrying out of about 40 miles of tunnelling, and was regarded as "a reliable assistant, being most exact in all his work and remarkably steady and persevering." From 1877 to 1880 he carried out on his own account contracts on the Rio Grande and Porto Alegre Railway, including some preliminary work in connection with the large bridge over the river Jacuhy. In 1880 Mr. French was appointed manager of the Dorstfontein Mining Company's works at Dutoitspan, in South Africa, for which he superintended the erection of engines, machinery and general plant, and three years later he became manager to the Bultfontein Diamond Mining Company. From 1885 to 1893 he was in business, for a time alone and subsequently with partners, as a contractor and mining engineer at Kimberley and Port Elizabeth, and for the last year of his life he practised in a similar capacity at Johannesburg.

Mr. French died at Johannesburg on the 30th of July, 1894, from pneumonia, after an illness of only four days. Throughout his career he was invariably successful in obtaining the respect and esteem, not only of his employers but also of those who served under him. He was elected an Associate Member of the Institution on the 5th of February, 1884.

WILLIAM HENRY MORROW, the son of a surveyor and land valuer of good standing in the north of Ireland, was born at Stranorlar, co. Donegal, in 1844. After being educated at Raphoe in the same county, he was engaged from April, 1862, to December, 1863, as an Assistant Engineer on the contract for the construction of the Enniskillen, Bundoran and Sligo Railway, and he was again occupied in a similar capacity on the same railway, for Messrs. Brassey and Field, from April, 1864, to March, 1866. From that date until December, 1868, he acted as an Assistant Engineer for Messrs. Brassey and Co. on the Bala and Dolgelly Railway. In 1869 he laid out the Fermoy and Lismore Railway (13 miles) for the late Mr. Thomas Brassey,[1] and in the same year he prepared, for Mr. Thomas Roberts of Portmadoc, plans and sections for the opposition to the Festiniog Railway Bill. During the period from 1870 to 1873 he carried out, amongst other things, the following work for Mr. Roberts: a survey of the underground workings of Holland's Quarry; parliamentary plans for the Portmadoc Waterworks; the setting-out of the Talsarnau-Trawsfynydd section of the Merionethshire Railway; and a survey of the town of Barmouth for sewerage purposes. He was subsequently engaged until March, 1875, for Mr. C. E. Spooner and Mr. H. U. McKie, on the construction of a portion of the North Wales narrow gauge railways, and from March to October, 1875, he acted as contractor's engineer on the Woodside extension of the London and North Western and Great Western Joint Railways.

From January, 1877, to September, 1878, Mr. Morrow was Resident Engineer for Mr. James Mansergh on the construction of the Southport Main Sewerage Works, which were carried out at a cost of over £120,000. He was then engaged for a time on various minor works, principally in connection with the slate quarries of North Wales.

In 1880 Mr. Morrow accepted an engagement with Messrs.

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[1] Minutes of Proceedings Inst. C.E., vol. xxxiii. p. 246.

Waring on railway work in Brazil, on the completion of which he obtained, in 1884, an appointment on the Buenos Ayres and Rosario Railway, as engineer in charge of the alteration works on the first section of that line. During the year 1887 he was in England for a short time on leave. In March, 1889, he proceeded to Cordoba, at the instance of the contractors, Messrs. Perry, Cutbill, De Lungo and Company, to take charge—under the Company's Engineer, Mr. John Carruthers—of the location and construction of a line, 153 kilometres in length, from that city to Cruz del Eje, since known as the Cordoba and North Western Railway. On the completion of those works in 1891, he started private practice as an engineer in Buenos Ayres. At the time of his death, which occurred suddenly, from apoplexy, on the 31st of August, 1894, he was employed on the Santa Fé and Cordova Great Southern Railway.

In spite of indifferent health Mr. Morrow was an indefatigable worker, both in the field and in the office. His ability and energy, combined with a considerate and generous disposition, made him everywhere respected and esteemed. He was elected an Associate Member of the Institution on the 2nd of December, 1879.

CHARLES HENRY ROGERS, third son of the Rev. George Rogers, M.A., vicar of Gedney, Lincolnshire, was born on the 12th of November, 1854, and was educated in Germany. In 1876, he went to Trinidad and became a pupil of the Hon. John Edward Tanner, Director of Public Works of that island. On the expiration of his pupilage in January, 1879, Mr. Rogers was appointed an Engineer in the Public Works Department of Trinidad, and soon became Chief Road Officer, which post he held at the time of his death. On several occasions he acted as First Assistant Engineer during the absence on leave of that official.

The opening out of roads within the colony, and the building of timber bridges, embankments and other works incidental to such service, far beyond the reach of the ordinary facilities of skilled labour and machinery, strongly developed Mr. Rogers' natural characteristics of self-reliance and resource. His energy and love of work induced him, unfortunately, to remain in Trinidad for thirteen years without taking leave of absence; ultimately a severe attack of fever compelled him to return to England in

1893. He was recalled on urgent affairs by the Colonial Government, in May of the following year, before he had fully regained his strength, and a severe attack of typhoid fever, acting upon a constitution already impaired by exposure due to the exigencies of his work, proved fatal on the 8th of November, 1894.

Mr. Rogers was elected an Associate Member of the Institution on the 2nd of April, 1889.

THE HON. GEORGIO CONSTANTINO SCHINAS, D.Sc., the son of a physician of eminence, was born at Malta on the 18th of July, 1834. His early education was conducted at the College of Ste. Barbe, Paris. Being a sickly boy, however, he did not remain there long, but, returning to Malta, he went to sea and made several voyages as an apprentice. In 1852 he obtained a mate's certificate, and four years later he was appointed instructor of navigation at the Naval School, Coxspicua. After fulfilling the duties of that post for a short time, he entered the Royal College or University of Pavia, where he graduated as Doctor of Science in 1861, and subsequently attended the Scuola di Applicazioni at Turin, from which he obtained in 1863 the diploma of a Civil Engineer. Returning to Malta he drew up, at the request of the Government, a report on the water-supply of that island.

In 1867 Dr. Schinas was appointed an examiner for the Civil Service of Malta, and in the same year he became Professor of Physics in the University of that island, a post which he held for nearly twenty years. In 1873 he received the thanks of the Government for a report on the acoustic properties of the Royal Theatre, and two years later he was appointed Consulting Engineer to the Sanitary Commission, in which capacity he took an active part in the sanitary reforms of that and subsequent periods. In conjunction with the Hon. E. L. Galizia, he proceeded in 1879 to Cyprus, to report on that island as a field for Maltese immigration. In the same year he was appointed Assistant Engineer to Captain T. J. Tresider, R.E., on the construction of the sewage works for the five fortified cities of Malta, which were carried out by the War Department at the joint expense of the Imperial and local governments. During the illness of his chief he took entire charge of the works, which were nearly completed in 1885, when he was appointed Resident Engineer on the waterworks then in course of construction under the direction of Mr.

Osbert Chadwick, C.M.G. These works consisted of about 30 miles of pipe-laying, six pumping-stations, six service-reservoirs, and a covered storage-reservoir of 11 million gallons capacity.

His engineering duties having become heavy, Dr. Schinas was obliged to resign the Chair of Physics at Malta University, of which he was appointed in 1886 examiner in the faculties of Arts and Science, and in the following year a Member of the Senate. In 1888 the Water and Drainage Departments, hitherto independent, were united to the Public Works Department, Dr. Schinas receiving the appointment of Superintendent of Public Works and becoming a member of the Executive and Legislative Councils of the island. In addition to the construction and maintenance of roads, public buildings, and water- and drainage-works throughout Malta and Gozo, the Public Works Department has in all technical matters the custody and management of the real estate of the Government—lands, farms and buildings, forming nearly one-third of the real property of the two islands, and producing a revenue of about £40,000. The duties, therefore, of the post of Superintendent of Public Works are varied and onerous, and to their fulfilment Dr. Schinas applied himself with characteristic zeal and energy. Many works of importance were carried out under his direction. A large poor-house, with modern sanitary improvements, was completed; and the system of water-supply was so extended that a constant supply of pure water became obtainable, not only in the fortified cities but in all the principal villages of Malta and Gozo.

Unfortunately Dr. Schinas' health gave way under the strain of these duties. In April, 1894, he was forced to apply for leave of absence, but the much-needed rest came too late—the heart disease, from which he was found to be suffering, was complicated by other troubles, and on the 26th of June he died suddenly, while engaged in conversation with the foreman of the drainage-works. To all he undertook Dr. Schinas applied a ripe theoretical knowledge, great practical experience, and sound common sense, while his energy and industry, combined with honesty and straightforwardness, gained for him universal esteem and respect. He was elected an Associate Member of the Institution on the 5th of April, 1887.

WILLIAM TOPLEY, F.R.S., was born at Greenwich on the 13th of March, 1841. After receiving some education at local schools, he passed to the Royal School of Mines, where he obtained his scientific training. In 1862 he was appointed to the staff of the Geological Survey of England, and the rest of his life was spent in connection with that department and in the advancement of the science of geology and of its applications.

Mr. Topley's first work in the field was in the Wealden tract, which, with its borders, forms so large a part of Kent, Surrey and Sussex. He began under Dr. C. Le N. Foster, and the two produced the remarkable Paper "On the Superficial Deposits of the Medway, with Remarks on the Denudation of the Weald," published by the Geological Society in 1865,[1] the main point of which was to show that the features of the country had been caused by subaërial actions, by rain and by rivers. This was the first of many Papers he wrote. When the survey of the tract in question was finished, Mr. Topley was the only man on the establishment who had had much to do with it, and the arduous task of writing a descriptive memoir fell to him. The result was the well-known book "The Geology of the Weald,"[2] by which his name will always be remembered. It is a masterly memoir, not only from the knowledge it shows of the extensive literature of the subject, but also from the way in which the questions of physical geology are treated, with most interesting chapters on the structure of the country, on the scenery, on the denudation, and on recent geological changes. To engineers, moreover, the chapters on economic geology are of great importance, and these refer to the old ironworks, to the possibility of the occurrence of coal, to water-supply, to building-stone, road-material, mineral manures, and to the distribution of population and of disease. Before this, however, Mr. Topley had brought his geological knowledge to bear on agricultural matters, including the relation of parish-boundaries to the chief features of the country.

When the survey of the Wealden tract was finished, Mr. Topley was transferred to the Carboniferous district of Northumberland and Durham; but, after several years in the North, he removed to London (in 1880) to take charge of the work of publication of maps, &c., at the Geological Survey Office. From that time he gave much attention to geological pursuits of a public kind. He entered into the work of the International Geological Congresses,

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[1] The Quarterly Journal of the Geological Society, vol. xxi. p. 443.

[2] Memoirs of the Geological Survey, England and Wales, 1875.

serving as secretary of the largest, held in London in 1888, and he also served on the Council of the Geological Society and of the Geologists' Association, of which latter he was President. He continued to work on the applications of geology, and one may here specially note the Reports of the British Association Committee on Coast Erosion, which owe so much to his secretarial labours, and also the collection of maps and sections in the Report of the recent Royal Commission on Metropolitan Water Supply,[1] besides various Memoranda in that Report, partly made at the request of the Commission.

Mr. Topley was, moreover, constantly brought into contact with engineers, for his wide knowledge, his conscientiousness, and the thoroughly trustworthy character of his work led to his advice being largely sought, and he became a great authority on questions of water-supply. He was consulted by the London Water Companies, by the London County Council, and by the Corporations of Birmingham, Bristol, Croydon and Hastings, as well as by many other authorities. He also helped greatly in the work of the Sub-Wealden Exploration Boring, and assisted Sir John Hawkshaw[2] in the Channel Tunnel project, with reference to which he wrote several Papers.

Of late years Mr. Topley gave much time to the study of the geology of petroleum, and it was indeed during a visit to Algiers in the autumn of 1894 in connection with this subject that he was seized with gastritis, probably through drinking bad water, an illness which proved fatal on the 30th of September, soon after his return home. In private life he was very happy, being loved and looked up to by a large circle of kinsfolk. His cheerful good nature, his kindness, and his readiness in giving information had also endeared him to many friends, and he is greatly missed by his colleagues of the Geological Survey, one of whom, Mr. H. B. Woodward, has drawn up a list of his works as an appendix to an Obituary Notice, a copy of which may be seen in the Library of the Institution.

Mr. Topley was elected an Associate of the Institution on the 12th of May, 1874.

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[1] In the Library of the Institution.
[2] Minutes of Proceedings Inst. C.E., vol. cvi. p. 321.

*** The following deaths have also been made known since the 4th of September, 1894:—

Members.

BARRINGTON, WILLIAM; *born* 14 March, 1825; *died* 12 January, 1895. (*Paralysis.*)

CHAPPÉ DE LEONVAL, THOMAS FLETCHER; *born* 3 December, 1824; *died* 14 January, 1895. (*Heart disease and bronchitis.*)

CHRISTIE, WILLIAM BUCHAN; *born* 16 November, 1847; *died* 11 June, 1894. (*Dysentery.*)

CLARK, EDWIN; *born* 7 January, 1814; *died* 22 October, 1894. (*Bronchitis.*)

GARNETT, GEORGE; *born* 2 January, 1820; *died* 18 December, 1894. (*Apoplexy.*)

JACOB, ARTHUR, B.A.; *born* 4 July, 1831; *died* 7 February, 1895. (*Bright's disease.*)

JONES, ROBERT; *born* 27 May, 1812; *died* 1 January, 1895. (*Intestinal ulceration.*)

KEMP, HENRY; *born* 9 August, 1839; *died* 29 January, 1895. (*Pneumonia.*)

KENNEDY, THOMAS STUART; *born* 26 April, 1841; *died* 17 November, 1894. (*Heart disease.*)

KNORPP, CHARLES BENJAMIN; *born* 1838; *died* 3 September, 1894. (*Paralysis.*)

LA TOUCHE, HENRY CHRISTOPHER DIGGES; *born* 2 September, 1839; *died* 16 February, 1895. (*Heart disease.*)

LLOYD, EDWARD JOHN; *born* 23 November, 1827; *died* 22 December, 1894. (*Heart disease.*)

RAVENHILL, JOHN RICHARD; *born* 15 April, 1824; *died* 28 December, 1894. (*Bronchitis.*)

REID, ALFRED GEORGE WOODWARD, C.M.G.; *born* 26 October, 1849; *died* 29 September, 1894. (*Malarial fever.*)

REYNOLDS, EDWARD; *born* 7 October, 1825; *died* 12 January, 1895. (*Cardiac asthma.*)

STRONG, JOSEPH FRANK; *born* 24 May, 1826; *died* 5 January, 1895. (*Paralysis.*)

SYMES, JAMES PAGE; *born* 22 October, 1842; *died* 25 January, 1895. (*Pneumonia.*)

VAWDREY, WILLIAM; *born* 17 April, 1840; *died* 2 January, 1895. (*Gout.*)

WILLIAMS, JOHN EVELYN; *born* 6 January, 1845; *died* 20 January, 1895. (*Kidney disease.*)

Associate Members.

CAMPBELL, GEORGE STEPHENSON; *born* 21 May, 1848; *died* 7 October, 1894. (*Typhoid.*)

FERGUSON, JOHN DUNN; *born* 29 February, 1864; *died* 14 April, 1894.

LATHAM, EDWIN DAVENPORT; *born* 8 January, 1843; *died* 21 November, 1894. (*Bronchitis.*)

MACGLASHAN, WILLIAM; *born* 26 July, 1865; *died* 2 January, 1895.

MAUGHAN, JAMES ARCHIBALD; *born* 11 June, 1843; *died* 20 December, 1894. (*Apoplexy.*)

NABHOLZ, KARL EMIL; *born* 3 May, 1856; *died* 24 May, 1894. (*Typhoid.*)

PRIESTLEY, ALFRED COVENEY; *born* 2 December, 1837; *died* 16 February, 1895. (*Bronchitis.*)

STANNARD, HARRY LAURIE; *born* 16 August, 1859; *died* 31 December, 1894. (*Malarial fever*).

WREATHALL, HARRY; *born* 30 March, 1866; *died* 5 September, 1894. (*Epileptic fit.*)

Associates.

D'AVIGDOR, ELIM HENRY; *born* 9 March, 1841; *died* 9 February, 1895. (*Intestinal obstruction.*)

ROSSER, WILLIAM; *born* 17 March, 1829; *died* 27 December, 1894. (*Paralysis.*)

Information as to the professional career and personal characteristics of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 26 February, 1895.

Sect. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

The Application of Photography to Surveying. By E. Monet.

(Mémoires et Compte rendu des travaux de la Société des Ingénieurs Civils, August, 1894, p. 216.)

The theory of the methods by which plans, sections or exact topographical measurements may be obtained by means of photographs, has been dignified by the title of the science of "photogrammetry." It originated with Colonel Laussedat in 1850, and has since been largely developed in Germany, Austria and Italy.

The principle of the method is simple. If a photograph be taken from a point whose position is already known, the direction of the axis of the object glass and the focal length of the lens being also known, and the line of the horizon being marked on the picture, then the picture can be laid down on a sheet of paper on which it is desired to plot the survey, and will give the direction from the point of observation of all the points in the picture whose position is required. Two photographs of the same objects taken from different known points define completely the position of each object, and also enable altitudes to be calculated or graphically determined.

As regards surveying, the method is exactly that of the plane-table, with the difference that a great part of the work which, with the plane-table, has to be done in the field is, with the photographic method, done in the office. In order to use a photographic camera for surveying, it must be specially fitted with the means of marking the horizon line on each picture and of observing horizontal angles. The focal length must be accurately known, as well as the extent of the field of vision exempt from distortion, and other optical qualities. A good lens specially suited for the work is indispensable. There are many types of apparatus in use, some of which are described and illustrated in this article. Some of them are specially arranged in all respects for surveying work, while others are adaptations of the ordinary photographic camera.

For ascertaining altitudes of points appearing in the photograph, the Author has invented a special instrument which he calls the "hypnometric rule." The elements for determining the altitude above the horizontal plane of vision are the perpendicular distance, in the picture, of the image of the point from the horizon line, and the distance of the point from the observing station, which

distance is known by plotting from two photographs as above described. The rule is made for the purpose of solving the equation of simple proportion by which the altitude is given. Other methods are also explained of obtaining altitudes directly from photographs.

C. F. F.

On the Construction of Wide-Span Roofs. By A. Föppl.

(Der Civilingenieur, 1894, p. 466.)

The history of the modern truss begins about sixty years ago with two discoveries: first, that a rigid figure in the plane is produced by joining triangles together; secondly, that if a system of bars, thus composed, is loaded, there are mainly only tensile and compressive stresses in the bars. Former triangulated systems like those of the Egyptians and Romans show that the first theorem was known long ago, but the constant introduction of members with bending stresses—different from those caused by rigid connections—also shows that the second theorem was not recognised as a pre-eminent rule of construction. The first trusses in the modern sense were the English and the German roof-trusses (the latter proposed by Wiegmann in 1839 and afterwards known as the "Polonceau truss") and the American bridge-truss. The theoretical definition of the stresses in the truss beginning about this time now made rapid progress, and has eventually been brought to a conclusion with the theories of the statically undetermined truss (Mohr, 1874) and of the secondary stresses (Manderla and others, 1880). Improvements will here still be made, but no more surprising discoveries. But in the application of the above theorems to trusses in space there is still much room for development. Two or more trusses braced together, as in roofs or bridges, are trusses in space, but in the calculation of the stresses they are usually treated as combinations of plane trusses. Schwedler, in his theory of cupolas (1866), was the first to establish a direct calculation of stresses of trusses in space. Designing a cupola with ribs according to the usual method, he discovered that the ribs were altogether dispensable, the surface of the cupola divided into triangles being rigid without the ribs. That theory dealt with uniform loads only. Subsequently the Author (1881) and others solved the problem for irregular loads. It was then to be expected that the discovery would be applicable not only to cupolas erected on a circular basis, but also to any triangular network completely enclosing a space; for example, a network described on a cylinder or the network of a polyhedron with triangular faces. Such a system would not only be rigid, but being built up of the smallest possible number of necessary bars would also be statically determined. If the polyhedron or cylinder is built half into the ground, so that a cupola or a shed-roof is produced, the

number of necessary supports is exceeded; and this being equivalent to an excess of necessary bars, the system is thus made statically undetermined. Mohr's method furnished the means of dealing with this case, but it would be advisable to cut out a number of real bars, so far as they are dispensable in respect of rigidity, in order to facilitate the calculation. The Author then describes his invention of a barrel-shaped network (*Tonnenflechtwerk*) arrived at by deductive reasoning. The calculation is given in outline, and it is stated that the network is not so economical as the common system of principals if heavy concentrated loads are assumed or if the cylinder is very long; but if the concentration is only such as in fact occurs on roofs, the network is more economical. For example, in the case of a cylindrical roof of about 98 feet span, 131 feet length and 40 feet height, the weight of iron exclusive of the screens was found to be 5·12 lbs. per square foot of covered ground. The dead load was assumed to be 24·57 lbs. per square foot, and the wind pressure per square foot of vertically exposed surface also 24·57 lbs.

M. A. E.

Iron Roof over Stone Arch Railway Bridge. By — PILTZ.

(Der Civilingenieur, 1894, p. 393.)

The stone arch, 146 feet span and 42 feet rise, which carries the Görlitz-Dresden line over the stream "Schwartze Röder," was finished in 1845. The arch ring is made of courses of sandstone, backed—for the sake of economy—with rubble, which on the faces of the arch ring is merged into ashlar blocks. The thickness of the arch ring at the abutments is 9·8 feet, at the crown 6·5 feet. Owing to insufficient protection from rain, the arch ring is completely saturated in wet weather. As some doubt as to the state of the arch ring arose, two shafts, one on each side of the crown, between the rails, each 64 square feet in section, were sunk to the back of the arch ring. The rubble masonry of the arch ring was found to consist of loose stones, the mortar being quite soft. The strength of Saxony sandstone is considerably reduced by continual wetting; it therefore became necessary either to dry the arch or rebuild it. Drying by means of a layer of concrete, and rebuilding of the bridge in iron, were rejected on account of the cost; and it was resolved to build an iron protecting roof over the arch. The roof consists of an iron framework, with thirteen principals united by seven purlins. The top of the framework is formed to a circular arc, and is covered with galvanized corrugated plate. The vertical sides of the framework are left open. The roof was erected in July 1892, and the whole of the arch is now completely dry. It was erected without interfering in any way with the traffic; the total cost was £960. This is, to the Author's know-

ledge, the first time a roof has been erected for the protection of a railway bridge against rain. The Paper is accompanied by three sheets of drawings.

A. S.

A Method of Measuring the Deflection of Iron Bridges.

By — Brill.

(Verhandlungen des Vereins für Eisenbahnkunde, 1894, p. 106.)

This method consists in obtaining the deflection of a girder by means of a wire stretched along it. The wire is fixed to one end-plate of the girder, and passes over a roller fixed to the other end-plate, and has a weight attached to its end. The roller is so fixed that it stands clear of the girder, and is graduated. The Author states that with a wire of 0·039 inch diameter, and a weight of 26·44 lbs., a reading can be taken accurately to 0·019 inch. The Author claims that by the use of this method the deflection can be taken easily, that no scaffolding is required, and that therefore the inconveniences of the usual methods are obviated. If it is required to take the settlement of the supports, the fixed points must be taken outside the girders.

A section is given showing the mode of application.

J. A. T.

Theory of Suspension-Bridges with Stiffening Girders.

By T. Godard.

(Annales des Ponts et Chaussées, August, 1894, p. 105.)

Until the publication of a Paper by Mr. Maurice Lévy in 1886 in the Annales des Ponts et Chaussées there existed no rational theory of the subject here treated of. Lévy's method assumes that at all times the suspenders (if equally spaced) bear equal loads, however unequally distributed may be the load. For a given condition of loading there is therefore only one unknown quantity to be determined, viz., the increment of stress in the suspenders. This is evaluated by expressing the total extension of the cable as a function of the vertical displacements of its various points, these again being supposed equal to the vertical displacements of the corresponding points in the girder. The deformation of the girder being calculable in terms of its loads and of the stress in the suspenders, the extension of the cable can be found in terms of the same quantities. But the extension of the cable can also be formed in terms of its horizontal tension. Equating these two expressions the stress in the suspenders is found.

The fundamental assumption of this theory, that the stresses in

the suspenders are equal, is only true when the girder is of very great stiffness. The Author attacks the problem in its most general form, assuming only that the cable is infinitely flexible, connected to the girder by suspenders at short intervals, that the girder is of constant moment of inertia, that the dip of the cable is within the limits of ordinary practice, and that the dead load, including the cable and its suspenders, is sensibly uniform. It is found that the stress in the suspenders, instead of being uniform under unequal loads, is given by a differential equation of a form recurring in many physical problems, viz.:—

$$\frac{d^2 \Delta p}{d x^2} = \kappa^2 \Delta p,$$

where Δp is the increment of stress in the suspenders per lineal unit of the bridge, at a point whose horizontal distance from the pier is x; κ^2 is an abbreviation for $\frac{N + \Delta N}{E I}$, in which N is the horizontal tension in the cable from dead load, ΔN the increment of N arising from the travelling load, I the moment of inertia of the girder and E the modulus of elasticity.

The general solution of this equation is:—

$$\Delta p = p_1 e^{\kappa x} + p_2 e^{-\kappa x},$$

where p_1 and p_2 are independent of x and are to be determined by the geometrical and mechanical conditions of the case. There are many different cases that may arise. The girder may be fixed or free at the ends; it may be supported by inclined ties from the heads of the piers in part of its length or the conditions may vary in other ways. A general method of proceeding is given in which thirteen unknown quantities appear, and thirteen relations sufficing to determine them. This method is then applied to the case of a girder resting freely at its ends with a single travelling load. The effect of the load and that of temperature, it is found, can be treated by superposition, and the effect of a continuous load covering part of the bridge can be found by integration from that of the isolated load. Formulas are established for the tension of the cable and that of the suspenders, and for the bending-moment and shearing-force at any point of the girder. The results are exhibited by diagrams, and tables are given to assist in the numerical calculations of any particular case. The only quantities entering into the formulas are the dead load per running foot, the span, the travelling load, the temperature modulus and the numerical quantity $l\sqrt{\frac{N}{E I}}$ which characterises the stiffness of the structure. The values of $l\sqrt{\frac{N}{E I}}$ are given for five existing French suspension-bridges in which it varies from 9·7 to 1·2.

The method is next applied to the case of a girder whose ends

are fixed, and a similar set of diagrams and Tables are given for this case. In both cases by making I infinitely great, Lévy's formulas are arrived at.

The following general conclusions are arrived at:—

(1) The factor $l\sqrt{\frac{N}{EI}}$ may be taken as an inverse measure of the stiffness of the bridge. When this factor is zero, Lévy's formulas apply strictly, and when it is not too great (say from 1 to 5) they give results of sufficient accuracy as regards travelling loads. They are not applicable, however, to the stresses arising from changes of temperature, nor are they applicable to travelling loads when the stiffening girder is very light.

(2) The less or greater stiffness of the girder has no appreciable effect on the tension in the cable. Almost the same tension is found for $I = 0$ as for $I = \infty$. It must be observed, however, that a large cable is not, as assumed, perfectly flexible, and that the stiffness of the girder relieves the cable from the local effect of the suspenders.

(3) Fixing the ends of the girder has no effect in relieving the tension on the cable, nor that on the suspenders. It diminishes the maximum bending-moment on the girder from travelling load, but increases the temperature stresses. On the whole, the advantage of fixed ends may be said to lie wholly in diminishing the amplitude of vibrations and more rapidly damping them.

C. F. F.

Bascule Bridge automatically worked. By — Roussel.

(Annales des Ponts et Chaussées, July, 1894, p. 39.)

This bridge, which has now been working successfully for two years, crosses a canal, just below a lock, to carry the towing-path from one side of the canal to the other. The bridge rests on a prolongation of the wing-walls of the lock, and is made to open and close automatically in the following manner.

A chamber is formed in the masonry beneath the tail end of the bridge, and is in communication by means of a pipe with the lock chamber. A wrought-iron cylinder floats in this chamber connected by links with the extremity of the bridge. Apart from this floater, the bridge is so nearly balanced on its horizontal shaft that only a small force is required at the end to open or close it as the case may be. When, therefore, the water is rising in the lock-chamber, the floater rises with it and closes the bridge; when the water is falling, the floater falls and opens the bridge. The distance of the floater from the shaft and the length of the links are so chosen that when the lock is open to the lower reach the bridge stands vertical, and that it comes down on its bearings when the lock is nearly filled.

If it is desired to use the bridge when the lock is empty it is a simple matter to close the bridge by hand, the effort necessary being small.

C. F. F.

Damage to Chimneys by Lightning. By C. Cario.

(Mittheilungen aus der Praxis des Dampfkessel und Dampfmaschinen-Betriebes, 1894, p. 384.)

The Author was commissioned to investigate the damage done by lightning to chimneys both with and without lightning-conductors. He invited communications on accidents which had happened to chimneys, and received particulars of twenty-four cases, which are discussed at some length in the Paper. He draws the following conclusions:—

(1) Lightning very seldom strikes a chimney in such a way as to leave any perceptible effect.

(2) The damage done by lightning to chimneys is in most cases inconsiderable: only in one case was a chimney actually destroyed; and in four cases only was the damage so great that it was necessary to pull the chimneys down.

(3) Lightning strikes chimneys both with and without lightning-conductors; the latter appear, however, to be struck oftener than the former. Of the cases reported on, two were with and fifteen without lightning-conductors; in four cases it was not definitely known whether a conductor was in position or not.

(4) In low marshy grounds lightning flashes seem to occur more often than in high and dry neighbourhoods.

(5) In one case only has lightning struck a steam-boiler so as to necessitate repair.

A. S.

Asphalt Pavements. By S. Whinery.

(Journal of the Association of Engineering Societies, Philadelphia, 1894, p. 488.)

An asphalt pavement may be briefly described as a street pavement of artificial sandstone, composed mainly of quartz sand cemented together with asphalt, and resting upon a proper foundation.[1] The sand should be quite fine, with grains of various sizes and having sharp edges. Limestone ground to an impalpable powder and residuum petroleum oil should also be mixed with the asphalt. The refined asphalt is melted and brought to a temperature of about 300° F., and after adding about 17 per cent. of residuum oil in order to soften it, the whole should be thoroughly mixed by blowing air into the bottom of the vessel in which the composition

[1] This description does not accord with received European opinion, which defines asphalt as a natural rock, mined like other minerals.

is heated. The air keeps the fluid mass in constant motion, thus securing the most perfect combination of the two materials, and the resulting compound is called asphaltic cement. The selected sand is also dried and heated to a temperature of about 320° F. in revolving drums placed in a furnace suitable for the purpose, and all grains, pebbles, &c., above a given size, should be removed by screening. The necessary amount of pulverized limestone is then added to the sand, and the several ingredients, in the proportion of 77 parts by weight of sand, 10 of limestone, and 13 of asphaltic cement, are next poured into a mechanical mixer with two sets of interlocking revolving blades, which very thoroughly mix the materials with each other in about one minute; after which it is conveyed in carts to the street and laid upon the previously prepared foundation in two successive layers, of which the lower is called the cushion coat and made about 5 per cent. richer in asphalt than the surface coat. After being evenly spread over the surface with shovels and rakes, each layer should be successively compressed, first by a hard roller and then by a steam-roller weighing from 5 to 10 tons, the rolling being continued as long as the roller will make the slightest impression on the surface.

The foundation upon which an asphalt pavement is laid must have sufficient strength to support the heaviest loads to which the pavement will ever be subjected, and this foundation should be practically indestructible and remain as a permanent structure, good for a century of use, even though the wearing surface of the pavement be repeatedly worn out and renewed. The most efficient foundation for an asphalt pavement is a bed of the best hydraulic concrete extending from curb to curb, which in streets with heavy traffic should be 6 inches thick. For suburban streets 4 inches of good concrete will suffice to give very satisfactory results.

It is a well established fact that an asphalt pavement can be kept clean for 20 per cent. less than granite or ordinary wood pavement, and its cleanliness implies that asphalt is also unobjectionable from a sanitary point of view. It is moreover the most comfortable to use, noiseless and pleasing in appearance; it is impermeable and non-absorptive, is not subject to organic decay or decomposition, offers the minimum resistance to the traction of, and causes the least amount of wear and tear to, vehicles. The difference in this respect between a rough pavement and asphalt in the cost of transportation is a factor so large that the questions of the first cost of the pavement, or of its durability, sink into insignificance when compared to it; and the writer quotes as an "eminent authority" Mr. Rudolph Hering, as having said:

"If 1 horse can just draw a load on a level road on iron rails, it will take
$1\frac{2}{3}$ horses to draw it on asphalt,
$3\frac{1}{3}$,, ,, on the best Belgian block pavement,
5 ,, ,, on the ordinary Belgian pavement,
7 ,, ,, on good cobble stones,
13 ,, ,, on bad cobble stones,
20 ,, ,, on an ordinary earth road,
40 ,, ,, on a sandy road.

"Therefore a city paved with sheet asphalt will save to itself and its citizens from 200 to 300 per cent. of the cost to it and them of transporting passengers and goods, as compared with a city paved with blocks. This saving will in a large city amount to thousands of dollars daily, and the yearly aggregate would doubtless be large enough to pave a whole city. It is a saving too which affects every person residing or owning property in the city."

The writer believes it is safe to say that, all things considered, an asphalt pavement can be constructed and maintained in first class order and renewed when necessary, at a smaller cost per square yard per annum than a pavement of granite blocks.

O. C. D. R.

The New Croton Dam on the Cornell Site.

(Scientific American, October 13, 1894.)

The first Croton Dam was built for the water-supply of New York in 1842. The original aqueduct leading from it practically followed a contour along the hillsides, but the new aqueduct, recently completed, follows a far more direct course regardless of the necessity for tunnels of varying lengths.

As it became manifest that the old Croton Lake was of insufficient size for the supply of New York other dams were built lower down the Croton River, increasing to some extent the amount of storage, but nothing was devised on a sufficiently large scale until the Quaker Bridge Dam was proposed to be built, crossing the valley through which the Croton River flows on its way to the Hudson River. This dam would have been the largest in the world. Mr. M. A. Fetley suggested instead of this a dam immediately below the present one but considerably higher. After much discussion an intermediate position was chosen for the new dam, called the Cornell site, 3½ miles below the old dam. This dam will provide a reservoir of 25,000 million gallons capacity in place of the present one of only 1,660 million gallons contents. The length of the masonry dam is 610 feet, and there is nearly the same length of earthen embankment with a rubble masonry core on one side, and on the other an overflow 1,000 feet long with its crest 14 feet below that of the dam. The masonry dam is 238 feet high from the rock foundation, and 188 feet thick at that place, and 21 feet 3 inches at the crest. It will rise 150 feet above the restored bottom of the lake, where it will be 109 feet 9 inches thick. The maximum height of the earthen embankment is 245 feet from the foundation, where its base is 550 feet wide; the crest is 30 feet wide and the slopes 2 to 1. The rubble core is 225 feet high, 18 feet thick at the base, and 6 feet at the top. The outside face

of the overflow weir is made up of a series of steps 8 feet high and 4 feet wide.

The Croton River will be diverted to one side by means of a cribwork dam, approximately semicircular in plan, which will form one bank of the new channel.

A. W. B.

The Carmel Reservoir for the Water-Supply of New York.

(Scientific American, November 3, 1894.)

The Carmel Reservoir has been made to supplement the water-supply of New York until the Cornell Dam is completed.[1] It is situated near the town of Carmel, on the west branch of the Croton River, 5 miles above what will be the northern limit of the new Croton Lake. Like the Boyd's Corners and Sodom reservoirs, it impounds, for use in dry weather, the flood-waters of the Upper Croton River, which would otherwise overflow the waste weir of the Croton Lake into the Hudson River. The reservoir has a maximum depth of 43 feet and a capacity of 7,500 million gallons. It has two dams of earthwork with masonry cores; the main one, which is 1,800 feet long, contains an overflow weir which has a length of 260 feet. The earthwork is 15 feet wide at the top with an inner pitched slope of 2 to 1 and an outer grassed slope of 2½ to 1; the masonry core is 10 feet thick at the bottom and 5 feet 6 inches at its top, 4 feet below the crest of the dam. The 300 feet over the natural channel of the river is built of masonry founded on the rock and contains the overflow, the outer slope of which is stepped; its extreme height is 74 feet, and the crest of the earthwork is 15 feet above the weir-level. The outlet consists of two 48-inch pipes, which are laid through the dam partly in a culvert and partly in the earthwork, and discharge on the apron at the foot of the overflow into the river channel. A valve-tower regulates the flow of water through the pipes.

A. W. B.

Supplementary Waterworks of Chemnitz.

(Deutsche Bauzeitung, 1894, p. 361.)

The town of Chemnitz has 150,000 inhabitants, and requires an average daily water-supply of 1,540,000 gallons, with a maximum consumption of 2,640,000 gallons. To meet this latter demand, an additional source of supply became necessary, and was obtained by collecting the water from one of the valleys feeding the River

[1] *Ante*, p. 422.

Zwönitz, near Einsiedel, by constructing a masonry dam across it. The reservoir so formed has a capacity of 79 million gallons. The area of the watershed is 667 acres, with an average yearly discharge of 176 million gallons. The greater part of the district is wooded.

The dam has a length of 590 feet and a maximum height of 66 feet above the ground surface; the foundations extend 26 feet below. Its breadth at the base is 66 feet, at ground-level 46 feet, and the top width 13 feet. It is curved to a radius of 1,300 feet. Its cubical contents amounts to 31,600 cubic yards, of which one-third is mortar. It is built of slaty rock, the mortar being composed of two parts of cement, one of fat lime and ten of washed sand. The water-face below the ground-level was covered with a 12-inch layer of concrete, and above that level it was plastered with cement 1 inch thick to render it watertight. The wall is surmounted by parapets, and a heavy cornice on the lower side, its line being broken near either end by a tower.

The valve-tower is situated at the centre and contains the usual draw-off valves, the outlet pipes passing inside a stoppered culvert through the dam. An overflow weir 82 feet wide is provided, with a suitable channel to lead away the storm-water. The water passes from the reservoir to a set of three filters, each 7,300 square feet in area, thence to a clear-water tank and, by means of a tunnel, to the vicinity of the town, where it unites with the old supply, and the two flow together into the service reservoirs of the town.

A. W. B.

The Shower-bath and its Arrangement in Public Baths, Barracks, Gaols, Factories and Schools. By Dr. Wolff.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1894, p. 407.)

The urgent need of public bathing establishments in Germany is insisted upon, and it is pointed out that, since the introduction of the shower- or spray-bath, many of the difficulties which beset the question of the provision of public baths, namely, those on the score of cost, have been removed. This is, in fact, at once the simplest and the cheapest form of bath; it requires only an area of 19·3 square feet per cell, of which space 10·7 feet are occupied for the bath proper, and 8·6 feet for the dressing-room. The best materials for construction, the mode of arranging the spray, and the proper temperature for the water in winter and summer are discussed. The volume of water needed for each bather is very moderate, as from 4·4 to 6·6 gallons suffice in barracks, and from 9·9 to 10·5 gallons in penal establishments, as against 39 gallons, a moderate consumption for a slipper-bath. In barracks, as soon as each soldier has had his douche, he retires to a common dressing-room; and it is found that 400 men can, by the use of eighteen shower-baths, complete their bathing in about one and a quarter hour, or 3·4 minutes per head. In gaols, where the prisoners

have to be kept separate, each man must dress in the bath-cell, and ten minutes per head are needed; the cost being 0·06*d.* per bath in barracks, as compared with 0·25*d.* per bath in prisons. In an existing building it is possible to fit up three shower-baths complete for £40, and a set of twelve baths will cost from £65 to £75.

The Author dwells upon the advantage to health of a warm, followed by a colder, douche, and he enumerates the ailments which may be traced to the employment of the shower-bath, but states that the former advantages compensate for these drawbacks. A sketch is given of the history of this form of bath, which was first introduced in Berlin in 1878 by the firm of David Grove, and a list is given of the public bathing establishments erected in Germany on this plan since that date. This form of bath is used also in the Moabit prison in Berlin, and in many other named penal establishments. The first shower-bath in a factory was that erected by the brothers Heyl & Co. for their dye-works at Charlottenburg, and a list is given of other manufacturers who have recently erected baths of this kind. The earliest bath in connection with a public elementary school was the one erected at Göttingen, under the auspices of the chief burgomaster, Mr. Merkel, and Professor Flügge, and the plan has been adopted in twenty-six other named towns. The provision of these baths has been a marked success. Some estimates of cost are given, and it is stated that the use of each school-bath entails a cost of 0·08*d.*

G. R. R.

The Recent Development of Canal Traffic in France.[1]

By C. Hardinge.

(Foreign Office Reports on Subjects of General and Commercial Interest, 1894. No. 342. With Map.)

After some remarks on the early history of canals in France, the origin of which dates from the Roman domination, and on the privileges granted for the improvement of river navigation and canals in the 15th, 16th, 17th and 18th centuries, the Report states that, at the time of the fall of the Monarchy in 1789, there were 1,100 miles of canal in France, of which 621 miles were open to navigation. During the period of the Revolution and first Empire very little attention was paid to the extension or improvement of inland navigation, and from 1789 to 1814 only 124 miles were opened to traffic, but 560 miles were added between 1814 and 1830. During the reign of Louis Philippe £13,600,000 were expended and 1,243 miles of canal were opened to traffic, but during the next ten years railways absorbed so much attention that the canals were neglected. In 1860 there was a

[1] The original is in the Library Inst. C.E.

reaction in their favour, and about £2,460,000 were applied to canal construction during the second Empire.

Between 1871 and 1878 the canalization of the Yonne, the deepening of the Seine from Paris to Rouen, and the improvement of the Burgundy Canal were amongst the important works undertaken by the State, and an increased impulse was given in the year 1879 when the Government drew up a statement advocating the construction of 870 miles of new canals, besides improvements in 2,237 miles of existing canals and in 2,486 miles of river navigation. The outlay required for the completion of these works was estimated at £28,000,000, and it embraced the introduction of uniformity in construction of all the locks in France, in length, in breadth, and in depth of water, which was a most important improvement. This programme passed into a law which was ratified by both chambers. It occasioned a rapid increase in the annual expenditure which rose from £1,200,000 in 1878 to upwards of £2,880,000 in 1883; but from that year forward was gradually reduced until it resumed the normal amount of £600,000 per annum, at about which it is now fixed.

The following Table shows the expenditure incurred by the State on the canal system from 1814 to 1891:

Years.	Amount.
1814–30	£5,967,173
1831–47	13,649,845
1848–51	1,511,681
1852–70	9,551,671
1871–78	5,105,654
1879–91	20,638,861
Total	£56,424,885

For several years previous to 1880 the Government received navigation dues which amounted to from £140,000 to £180,000 per annum, but such bitter complaints were raised against this taxation by the barge industry that in 1880 all navigation dues were suppressed, and at the present time the only charges made by the State in connection with inland navigation consist in some payments exacted for fishing in rivers, for the hire of fore-shores, for timber cut from the plantations on the banks, and for concessions of towing-monopolies; these together amounted in 1891 to about £100,000.

The law of 1876 divided the waterways forming the chief lines of communication into principal and secondary lines. On the first of these a minimum depth of water of 6 feet 6 inches is obligatory, and the locks are required to be at least 126 feet long by 17 feet broad; dimensions which were chosen in order to ensure the free circulation on canals in France of the ordinary Flemish barge of 300 tons, which is 125 feet long by 16½ feet broad and draws 5 feet 10 inches of water. By the year 1892 these dimensions had been given to no less than 2,548 miles of navigable waterways in France; and whereas canal navigation had

previously been confined to merely local transport, barges of 300 tons burthen can now navigate direct from Havre to the frontier of Alsace, or from Dunkirk to Lyons.

The new conditions have given a great impetus to the carrying trade on inland waters, and, whereas in 1881 the weight of goods carried on canals was 19,740,000 tons against 85,060,000 tons carried by rail, this proportion had risen by 1891 to 25,200,000 against 104,800,000, although during the same period the length of railways increased 50 per cent. (from 14,625 miles in 1881 to 21,875 miles in 1891), while the length of the canals in use only increased by a fraction more than 3 per cent.

The goods transported by water consist chiefly of heavy merchandise, such as building materials (32 per cent.), mineral fuel (28 per cent.), agricultural and alimentary products (14½ per cent.), wood (8 per cent.), minerals (7½ per cent.), and manures (5½ per cent.).

There is also a considerable international canal traffic, chiefly between Belgium and France, but also over canals connecting the Rhone and the Rhine and the Moselle and the Rhine. Two-thirds of the traffic with Belgium consists in the importation of coals from the districts of Mons and Charleroi. Steam barges were used in 1892 on only 2,912 miles of canal, and they carried 780,382 tons of merchandise.

The extent of inland navigation in 1891 was 7,702 miles, of which 7,169 were under the management of the State, and the remaining 533 had been granted to concessionnaires. A census taken in that year showed that of 15,925 barges then in use 4,191 exceeded 300 tons, 3,297 were from 200 to 300 tons, 2,459 from 100 to 200 tons, 2,892 from 50 to 100 tons, and 3,085 from 3 to 50 tons. Of these, 8,067 were decked boats, and 7,858 undecked; 1,051 were built of iron, and the rest of wood; 13,699 had cabins, and 2,226 had none; they were manned by 19,579 men, with 7,917 women and 12,972 children; 2,094 of the boats were provided with stables on board to house the animals used for towing, viz., 1,396 horses, 186 mules, and 1,604 donkeys.

On rivers like the Seine, the traction is performed by screw and paddle-tugs, and also by submerged chain. In the north and east of France it is generally performed by relays of two horses under the charge of a carter, and with this system barges are able to cover from 10 to 20 miles a day, according as there are more or less locks to pass through. Sometimes the horses belong to the owner of the barge, and are stabled on board; sometimes they are provided by the State, or by contractors having a monopoly, at an average cost of $\frac{1}{25}$ of one penny per ton per kilometre; but the system which is most general is to depend upon horses belonging to professional towers, or to the riverain farmers who let out their horses at seasons when they are not required in the fields and withdraw them when the seasons for ploughing, sowing, or harvesting begin.

In the centre of France the boats are generally towed by the bargee and his family, with or without the assistance of a donkey

kept on board, but this system is only applicable for small boats, and is very slow and tedious.

On a few canals where the movement is very great the traction has been undertaken by the State with the greatest possible success, and it has contributed enormously to the development of traffic in those regions.

In 1881, for long distances, the prices of freight for coal from the mines of the Nord and Pas de Calais varied from $\frac{1}{7}d.$ to $\frac{1}{3}d.$ of a penny per ton per kilometre, and averaged about $\frac{1}{4}d.$; but much competition has reduced this to an average of about $\frac{1}{7}d.$, and sometimes the price sinks as low as $\frac{1}{10}d.$ per ton, which is within the very narrowest margin of its actual cost.

Much still remains to be done in order to complete the organization of canal navigation; for, with few exceptions, there are no cranes for the manipulation of heavy merchandise; no railways connecting the canals with the railway system; no warehouses for stowing goods before loading, or after unloading; and no means for obtaining information with a view to getting a fresh cargo.

A map of the French canal system is annexed to the report.

O. C. D. R.

Origin and Progress of Navigable Waterways in the Empire of Russia.[1] By E. F. DE HOERSCHELMANN.

(Aperçu historique du développement des Voies Navigables de l'Empire de Russie. Kief, 1894.)

The abundance of water in many Russian rivers, which render them navigable without any artificial improvement, caused them to be used for commercial purposes at a very early period. The Bulgars, who possessed themselves of the Lower Volga in the sixth century, established their capital at the ancient city of Bolgary, which stood at the junction of the River Kama with the Volga, and are known to have used both these rivers for navigation in the tenth century; and again, at the confluence of the Rivers Mologa and Volga, there existed a city called Kholopi-Gorodok, where a great fair was annually held from the fourteenth to the sixteenth century, to which Russian and foreign merchants brought their goods from great distances by water. Novgorod, on Lake Ilmene, the most ancient commercial city in Russia, owed its importance to the circumstance that it was situated close to the navigable river Volkhoff, and so near to the watershed which separates the rivers running northwards into the Baltic and southwards into the Black Sea and the Caspian, that only a short distance of less than 2 miles between them required land transport. So far, however, as is now known, no attempts were made to improve the navigable routes by art until the latter half of the sixteenth century, when Selim, Sultan of Turkey, commenced to

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[1] The original is in the Library Inst. C.E.

cut a canal in what is now the Russian Province of Saratoff, with the object of connecting the River Ilovla, an affluent of the Don, which flows into the Sea of Azoff, with the Kamychennka, which flows into the Volga and thence into the Caspian. This work was, however, left uncompleted.

Peter the Great was the first Russian sovereign who conceived the idea of creating a vast system of internal navigation which should unite all the principal rivers of Russia, and he devoted himself with great energy to the execution of this project, which was inspired by what he had personally observed during his residence in Holland. In 1702 a body of carpenters, masons, brick-makers, and stone-cutters was contracted for and conveyed by the Russian Government to St. Petersburg in order to construct canals, and the Vychene Volotski canal still retains some lock-gates built at that time on Dutch models. Towards the end of the seventeenth century he ordered the canal commenced by the Sultan between the Volga and the Don to be completed; and when Colonel Broeckel, the Director of the works, failed to surmount the difficulties, the Emperor appointed Captain Perry, an English engineer, as his successor. Good progress was then being made when, war with Sweden having been declared, the troops by whom the canal was being constructed were withdrawn, and the works again abandoned. The history of this unfinished work has been published in Dutch by the Russian Admiral Cruys, and recently (1886) in French by Mr. Léon Don on behalf of a Franco-Russian company which proposes to modify the original project, and, following the course of the valleys of Proudovaïa and Yagodnaïa, rise to a height of 280 feet above the Volga by means of twenty-one locks. The total length of the canal would be 53 miles, with cuttings for 2½ miles near the summit ranging from 105 to 140 feet in depth, and locks supplied with water partly by means of catch-water basins and reservoirs and partly by raising it from the Volga by steam-pumps. Canal-boats are proposed, 210 feet long by 42 feet wide, and the total cost of the work is estimated at £2,800,000; but the project has not yet received the approval of the Russian Government.

Peter the Great endeavoured also to unite the Don and the Volga at another point by a canal starting from the source of the Don in the little lake of Ivanofskoïe and terminating in the small River Chate, which runs into the Oupa and thence into the Oka, one of the main affluents of the River Volga. More than twenty locks had been built by the year 1707; but in 1711 the works were interrupted, and, the supply of water having proved to be very limited, they have since been abandoned and all the materials definitely disposed of.

Vychene Volotski Canal.—The object of the Vychene Volotski Canal, upon which the Dutch artificers were employed in 1702, was to connect the basin of the River Volga with the great Lake Ladoga, north-east of St. Petersburg, and thus also with the Baltic Sea. This was done at small expense by cutting a short canal from near the source of the Tvertza—a tributary of the

Volga—to the River Tsna, with locks at each end; but some dangerous rapids on the Msta River, into which the Tsna runs, made the navigation so unsatisfactory and so tedious that continual works of amelioration were required upon it during the succeeding fifty years. Eventually it became a very important artery for provisioning St. Petersburg, and by the year 1757 the annual traffic amounted to 200,000 tons of merchandise. Further improvements introduced between 1830 and 1850 allowed the carrying power of the vessels on the canal to be increased from 82 to 115 tons; and its importance as a navigable highway culminated at about the middle of the present century, after which it was to a great extent superseded by other routes better adapted to the exigencies of commerce. The railways from St. Petersburg to Moscow, and from Novotorjski to Rybinsk-Bologoïe, together with the Marie navigable highway, have drawn away all the through traffic from the Vychene Volotski canal, and the latter is now only used for limited local purposes.

Marie Canal and Navigation.—The Marie navigable highway, which by recent improvements has been rendered available for vessels of 295 tons, and is still undergoing further ameliorations of great magnitude that will make it by far the most important waterway in all Russia, leaves the Volga near the town of Rybinnsk, and, following for 269 miles its affluent, the Cheksna, as far as Lake Bielo-Ozero, passes through this lake and into the River Kovja, up which it proceeds, with the aid of two locks, until it reaches the watershed between this river and the Vytegra, a tributary of Lake Onega, which again is connected with Lake Ladoga by the River Svir. Both these lakes are furnished with conterminous canals, and connected by the River Neva with St. Petersburg and the Baltic. The rivers Kovja and Vytegra are united at the summit by means of the Marie canal; and the Cheksna river serves the double purpose of connecting the Volga also with the White Sea, it having been joined in 1825–28 by the Duke Alexander of Wurtemburg canal to Lake Kubennskoïe, from whence issues the large River Sukhone, affluent of the Northern Dwina, which flows into the White Sea.

Tikhvine Canal and Navigation.—A third route connecting St. Petersburg with the great basin of the Volga is the Tikhvine waterway, which was among the projects originated by Peter the Great, although the execution of the work was not commenced until early in this century. Leaving the Volga a little above Rybinnsk, this route follows up the River Mologa and its affluent, the Tchagodostscha, until the watershed is reached. The Tikhvine canal carries it across the summit to the Tikhvinnka river, which runs into the River Siasse and into Lake Ladoga. The canal-boats are 63 feet by 14 feet, and of 32 tons burthen; but the works have never been properly completed, and, although as many as 6,000 vessels did at one time pass annually over this route, the competition of the Petersburg-Moscow Railway has now reduced that traffic to one-third.

Canals connecting Dnieper and Niemen, Dnieper and Vistula, Niemen and Vistula, Dnieper and Western Dwina.—Other waterways of some importance unite the River Dnieper, which runs into the Black Sea, with rivers flowing into the Baltic. The Oguinnski canal connects it with the Niemen, passing through Lake Vygonofskoïe; and the Dnieprovski-Bougski canal with the Vistula. The waters of the Niemen also communicate with the Vistula at a lower point through a third canal, built in 1824–1829, which passes by the town of Augustof, and the Dnieper is again connected with the Baltic at Riga through the Berezinnski canal, which unites the waters of the Berezina river, a tributary of the Dnieper, with those of the Western Dwina, which flows into the Gulf of Riga. This canal was first built nearly 100 years ago, but had been much neglected. Improvements commenced in 1878 and still continued, have largely increased its traffic; as many as 16,000 rafts of timber are now annually conveyed by it from the forests in the interior to the Port of Riga.

Canalization of Rivers.—The above enumerated works have had for their principal object the connection of navigable rivers flowing southwards towards the Black Sea, the Sea of Azoff, and the Caspian with other rivers flowing northwards into the Baltic, or into the large lakes which lie to the north-east of St. Petersburg, and into the White Sea. But in other parts of Russia large sums have also been expended in canalizing rivers for internal navigation. Thus the Moskwa river, running past the ancient capital of Moscow, was taken in hand by a private French company, to whom a fifty years' concession was granted in 1873. By constructing locks, dams, and other works at an expenditure of £300,000 they have created a navigable highway from Moscow to the Volga, and between Moscow and Kolomna, where the Moskwa river runs into the Oka (100 miles), have created a traffic which has latterly reached 200,000 tons of merchandise per annum, in addition to a very large trade in timber.

The chief works, however, have been undertaken at the cost of the State. Two of the largest rivers in Siberia, the Obi and the Yenissef, have been canalized since 1883 at an expenditure of £300,000, and a navigable waterway created of about 3,300 miles in extent from Tumene to Irkutsk. In Finland also, at about the same cost, a large canal, 36 miles long, has been cut from Willmannstrand to the Baltic, and a succession of lakes extending far into the interior of the country has within the last forty years been by this means connected with a seaport. Between the towns of Rybinnsk and Tver, on the Upper Volga, very considerable works have been executed, and also below Rybinnsk the channel has been deepened in many places. At Nijni Novgorod and at Saratof something like £1,000,000 have been expended on quay-walls, &c., and in deepening the River Volga; and the several mouths of the river, where it flows into the Caspian Sea, have required constant dredging to keep the navigation open.

Extensive canalization works have also been carried out on the

rivers Vistula, Dniester, Dnieper, Peripete, and the Northern and Western Dwina, with lesser works also on the rivers Don, Niemen, Oka, Kama, Desna and others; but much yet remains to be done before their navigation can be considered equal to modern requirements.

Surveys and Studies.—A special commission was created in 1875 with the object of perfecting a system of river navigation in connection with, and as feeders for, the main lines of railway, and during the succeeding ten years about 20,000 miles of waterways were surveyed. Three hundred and fifty posts were established by this commission, where periodical observations of the depth of water and of the state of the rivers at different seasons are systematically noted, tabulated, and remitted to the Minister of Highways for publication; and they also created meteorological and hydrometric stations on the chief rivers. The data thus collected have indisputably proved that the rivers of Russia are better adapted for navigable highways than those of other European countries. Their greater abundance of water, their greater extent, and the general sluggishness of their current are all in their favour, and the inequalities of the land-surface are so slight that it is comparatively easy to unite the several waterways into one connected general system. The Volga has not one rapid for a distance of about 1,900 miles from the Caspian Sea; and, with the exception of the Dnieper, the same exemption characterises all the other principal rivers. The Dnieper has several rapids at one spot, which divides its course into two parts. Above these rapids the river is navigable for 933 miles, and below them for 218 miles.

The following particulars concerning the canals and navigable waterways of Russia show how they compare with those of some other European countries.

Countries.	Length of Navigable Waterways.	Weight of Goods carried on the Waterways.	Weight of Goods carried 1 mile.	Average Distance over which each Ton of Goods was conveyed.	Annual Sums expended by the State	
					on Improvements on the Navigable Waterways.	on Maintenance of the Navigable Waterways.
	Miles.	Tons.	Ton-miles.	Miles.	£	£
Russia . .	52,817	32,762,000	20,738,346,000	633·0	206,100	331,200
France . .	7,939	23,320,000	1,970,540,000	84·5	1,920,000	612,000
Germany . .	6,214	13,700,000	2,979,750,000	217·5	345,000	180,000
Austro-Hungary . .	3,728	2,620,800	..	..	£550,000	
Belgium . .	1,000[1]	..	369,100,000	..	300,000	120,000
England . .	2,641	36,855,000	1,372,849,000	37·25		

[1] The State owns 1,000 miles of Belgian waterways. Including 380 miles belonging to private owners, the total length of navigable waterways in Belgium is 1,380 miles.

The above statistics show that the extent of navigable waterways in Russia is more than double the united length of those in the five other countries, and the number of ton-miles that goods are carried is nearer three times.

The annual expenditure of the State on these waterways averages per ton-mile:—

	Centimes.
France	1·99
Belgium	1·77
Germany	0·27
Russia	0·04

O. C. D. R.

The Great-Chicago Canal.

(Scientific American, October 20, 1894.)

Chicago is situated on the watershed which separates the waters flowing into Lake Michigan on the east, including the small stream called the Chicago River, winding through that city, from those discharging into the Gulf of Mexico on the west, including the Des Plaines, Illinois and Mississippi rivers. The Des Plaines River joins the Illinois River, and that flows into the Mississippi a short distance above the mouth of the Missouri. Lake Michigan is 10 miles and the Chicago River 2 miles distant from the Des Plaines River.

At present the sewage of Chicago runs into Lake Michigan, threatening with contamination the water-supply of the city, although its intake is situated some miles out in the lake. The canal is intended to avoid this pollution by conveying the sewage of the city down the Des Plaines River valley to the lower river, near Joliet, and incidentally to accommodate barge traffic. The discharge of the Des Plaines River varies from a quite insignificant quantity up to 800,000 cubic feet per minute, consequently the construction of a canal through its valley has involved the excavation of 13 miles of new river channel parallel with that of the canal, with an overflow weir at its upper end to conduct the surplus waters to Lake Michigan when its discharge exceeds 300,000 cubic feet per minute; also 19 miles of embankment had to be made to keep the river-water out of the canal. From the mouth of the Chicago River—the commencement of the canal—to Joliet is 35 miles, and the excavation for the canal is in places 50 feet deep, the width of the canal in rock is 162 feet, with a depth of 22 feet, and in earth the bottom width is 202 feet. The maximum fall is 10 feet per mile, which provides for a discharge of 600,000 cubic feet per minute, enough for the sewage largely diluted of 3,000,000 persons.

The portion of the canal being constructed is in the hands of numerous contractors, each excavating with plant of his own choice. This results in a varied class of machinery. It includes

the direct use of horses, Bates hydraulic dredge, in which a wheel with blades rotating on a horizontal axis chops up the strata, which is drawn into a pipe by means of a rotary pump and forced through a long pipe to a distance of several thousand feet if necessary. The Brown cantilever is another machine employed; it travels on rails on the bank of the canal, and the cantilever, 342 feet long, provides an inclined track up which the material excavated in the dry is carried in buckets. The wire rope-way, cheaper than the latter in first cost, compares favourably with it in execution. The trestle-piers move on rails on the banks, to which the excavated material is run along the rope.[1]

A. W. B.

Sluices for Mill-Weirs. By — Barbé.

(Annales des Ponts et Chaussées, July, 1894, p. 32.)

The River Toucques, passing through the town of Lisieux, is subject to floods, the violence of which was much increased by weirs, which retained the water to provide power for mills. The reconstruction of these weirs formed part of a scheme of protection for the district against inundation.

The work was carried out by the Government, but the working and maintenance of the weirs when finished is confided to the mill-owners, and the condition was imposed that each sluice should be capable of being raised by one man (by hand-power only), with a head 6 feet 6 inches against it, the construction being at the same time of a simple and substantial character. The clear opening of each sluice is 13·1 feet in width, so that the pressure on it is very considerable. In order to facilitate the lifting, the sluice is made in two panels, with a horizontal joint. The lifting rods are attached to the lower panel only. When the lower panel has lifted a certain distance it engages with the upper panel and the two move together. Conversely, in lowering the sluice, the upper panel comes to rest on fixed stops while the lower one continues its motion down to the sill. A rubber flap is used to close the joint between the panels. A counter-weight is used equal to the dead weight of the two panels together. By the time the upper panel begins to move, the greater part of the head of water has disappeared and the friction is much reduced. In the first sluices made on this plan the lower panel was placed on the up-stream side of the upper panel. The contrary position was afterwards adopted and is preferable. The cost of the sluices, for all ironwork, amounted to £2 12*s.* per square foot of surface, the weight of iron being 205 lbs. per square foot.

C. F. F.

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[1] Minutes of Proceedings Inst. C.E., vol. cxviii. p. 483.

Ice-Boring Machines for River-Surveys. By J. Ripley.

(Engineering News, New York, vol. xxxii., 1894, p. 288.)

In the improvement of the navigation of the St. Mary's river, Michigan, it was necessary to make detailed surveys of all the shoals. These were generally made in the summer, but since 1870 soundings have been taken in the winter through the ice at places where it was necessary to check the amount of the season's work. Various devices were considered for making the holes in the ice with rapidity. Augers were successfully used for three months in the winter of 1893–94; the average work of two men with a machine being equal to that of twelve to fifteen axe-men. The auger is made by bending a bar of $\frac{3}{4}$-inch square tool steel in a spiral round a $1\frac{1}{2}$-inch round bar, the lower end being drawn into a chisel edge, which is widened to $1\frac{3}{16}$ inch so as to clear both the inside and outside of the spiral. The revolving motion is transmitted to the auger by turning a crank fastened on the shaft of the driver of the bevel gearing. In the first machine the gearing was 48 to 24, the diameter of the driver being 9 inches. In the second, the gearing was 52 to 17 and the diameter $13\frac{1}{2}$ inches. They would cut through 1 foot to 3 feet of frozen snow and 24 to 30 inches of ice in eight seconds, twelve turns of the handle of No. 2 being necessary to eighteen of No. 1. At the present time three machines are in use.

Soundings are taken with pine or spruce poles marked into feet and tenths of a foot. The party employed in making the ice-surveys camp out in tents. The organization is as follows: an engineer who records the soundings, two men for sounding, six men to work the three boring machines, two men to move the cord lines and to mark the places at every 10 feet where the holes are to be bored, two or three men to shovel the snow after the holes are bored so that the sounders can see the water surface, one water gauge observer and one cook. The cost of such a party is £200 per month, and an average of 3,000 holes can be made per day of eight hours, the cost per sounding being less than 1*d.*

B. H. B.

Concrete Lining at Mullan Tunnel. By H. C. Relf.

(Journal of the Association of Engineering Societies, Philadelphia, 1894, p. 432.)

At the crossing of the main range of the Rocky Mountains, under a summit 5,855 feet above sea-level, the Mullan tunnel, on the Northern Pacific Railway, is 3,850 feet long, with a rising gradient going west of 1 in 50 and on a continuous curve. It has been driven through a material so treacherous that serious accidents have frequently occurred which interrupted the traffic.

When first constructed in 1883, about half the tunnel was timbered with posts, 12 inches × 12 inches, 4 feet from centre to centre and sometimes closer, and more timber had been added from time to time, sometimes placing duplicate sets inside the original posts. The rock is mostly syenite, interspersed with granite boulders and streaks of clay, through which there is a considerable seepage of water.

A masonry lining involved the removal of all the timbering, and the work had to be done without interrupting the traffic, the tunnel being only 16 feet wide, with a single line of rails. However, after long deliberation, in July 1892 it was decided that side-walls, 2 feet 6 inches thick, should be constructed, composed of concrete up to a point 6 inches above the springing line of a semi-circular arch of brick. The mortar consists of 1 part English Portland cement to 3 parts of sand, and to this are added 6 parts of broken quartzite from a slide 20 miles west of the tunnel, which requires very little extra breaking to make the size suitable. A dry-cement spiral mixer, driven by a 15-HP. engine on an 8-foot shaft running in a trough, carries the cement and sand from a hopper at one end (mixing it meanwhile) to a shoot at the other, which deposits it on the top of a staging-car, where it is mixed with water as required.

The timber in the tunnel is removed in short sections and replaced by posts, set at the proper distance from the centre line, with 2-inch planks behind them fixed by wedges. The planks are raised as the work proceeds to the height required for confining the concrete. Sufficient mortar to make an 8-inch layer of concrete is first run into the section from the top of the car by means of the chute; the mortar-car is then moved to another section, and broken stone, from another car in attendance, is shovelled into the first section until it has taken up all the mortar. This operation is repeated at several succeeding sections before returning to the first one, which by that time is ready for a second layer of concrete; and the same thing goes on until the wall is carried up to the proper height. Wherever the excavated space would make the wall more than 2 feet 6 inches thick a back mould is used, and the space behind the concrete is filled with dry stones carried up simultaneously with the cement.

After twenty-four hours the wall is hard enough to stand the removal of the plank-lagging for use at other sections, and in from ten to fourteen days is sufficiently strong to support the arch. The bricklayers use two high staging-cars similar in construction to the cement-car; one of them supplied with brick and the other with dry cement-mortar, in the same manner and in the same proportions as for concrete.

The work was suspended during the winter of 1892–93, but by the 12th of August, 1893, the side-walls of 1,570 lineal feet of tunnel had been built. On the 15th of September, 1893, the work of arching commenced; 950 feet of it have been completed and it is still in progress.

The average daily progress was 30 lineal feet of side-wall containing 45 cubic yards of concrete, or 3 cubic yards per lineal foot of tunnel. The average cost per cubic yard was under 33*s.*, including all labour required in the removal of timber, work-train service, lights and tools, engineering and superintendence and interest on plant.

The arch is 20 inches thick, being built with four rings of large bricks $2\frac{1}{2}$ inches $\times$ $4\frac{1}{2}$ inches $\times$ 9 inches. This gives 1·62 cubic yard of brickwork per lineal foot of tunnel, and the present cost is about £3 11*s.* 6*d.* per cubic yard, or £5 15*s.* 10*d.* per lineal foot of tunnel.

Up to this time the total cost of the work has averaged about £10 per lineal foot of tunnel, but during the present year it will probably be rather less. It will require about eighteen months more to complete the remainder of the side-walls and arch.

O. C. D. R.

The Application of Motive-Power to Road-Carriages.

By GEORGES BRABANT.

(Le Génie Civil, vol. xxv., 1894, pp. 259 *et seq.*)

In a series of five articles the Author discusses the problem of constructing a carriage fitted with steam- or other motive-power for use on common roads, and reviews the carriages submitted in competition for a prize recently offered for such a carriage by the *Petit Journal* of Paris.

The essential conditions to be fulfilled by a successful design are those of safety, speed, power and facility of manœuvring. Other qualities to be regarded, though not essential, are those of weight and cost.

The Author considers that certain types of carriage already constructed satisfy the essential conditions, but are capable of improvement in detail.

The possible speed is largely governed by the mode of suspension of the vehicle and by the state of the road. On a macadamised road in fair order, a speed of 12 to 15 miles per hour may be made, but this cannot safely be exceeded except on unusually good roads. The resistance to traction should be estimated at $6\frac{1}{2}$ per cent. of the weight, a figure corresponding to a good road in bad weather. A simple calculation shows that on this basis the motor requires to be of 5 HP. for each ton of weight for a speed, on the level, of over 12 miles per hour, or, on a gradient of 1 in 10, a speed of nearly 5 miles per hour. The resistance is subject to extreme variations, and therefore the motor requires to work with economy through a wide range of effective power.

The Author considers that some of the competitors for the prize above mentioned, were mistaken in supposing that new types of motor were required for achieving the desired results. He thinks

the difficulty of the problem to lie entirely in securing the proper combination of simple and well-known elements.

Electricity, compressed-air, oil and steam have all been tried for road-carriages. The first two, as far as present experience goes, are quite unsuitable. Very successful carriages have been made with oil-engines, among which the Daimler motor is specially notable. The Author considers that where lightness and elegance are the chief requisites, the oil-motor may have a large field for employment; but where economy in working and maintenance and adaptability to a wide range of conditions have to be regarded, that is to say, for most practical purposes, the ordinary steam-engine has a marked superiority.

Attention is called to the fact that the use of steam-carriages has been prevented by regulations which are almost prohibitory and are unnecessary. Experience shows that a well-designed steam-carriage is less dangerous, both to its passengers and to other traffic, than a great part of the ordinary wheeled traffic of the streets.

The steering of self-propelling carriages raises important questions. The method invented by Mr. Jeantaud, called the "broken axle," is highly spoken of. In this system the front axle is in three pieces, the middle piece being forked at the ends and jointed (with vertical axes of rotation) to the end pieces on which the wheels are fitted. Each of the end pieces has a horizontal arm projecting from it, and the two arms are again coupled by a rod whose movement is commanded by the steering lever. When the steering lever is moved, the two front wheels turn through different angles, while the middle part of the front axle remains parallel to the rear axle. This gives in practice very good control, while the very short lever arms on which the front wheels are pivoted reduces very greatly the effect on the steadiness of running produced by the roughness of the road. It is desirable that the main part of the weight should be carried by the rear axle, and that the front wheels should be wider apart than the rear wheels.

The construction of the wheels leaves more room for improvement than any other part of the self-propelling carriage. With heavy loads and high speeds the effect of the continual hammering is very destructive to tyres, while some types fail as driving-wheels for want of rigidity. A really good elastic tyre of sufficient strength and endurance is still a desideratum. The method adopted by Messrs. de Dion and Bouton of applying the power direct to the rim of the wheel without transmitting it through the spokes has great merit.

Proceeding to the description of carriages sent in for the above-mentioned competition, the Author describes and illustrates four carriages with oil or benzine motors. The lightest of these weighs only 10 cwt. and carries four persons. Four steam-carriages also are described and illustrated, all of which possess interesting features. That exhibited by Mr. Le Blant has been purchased by

a large retail firm for the distribution of their goods in the suburbs of Paris, and ten similar carriages have been ordered by the same firm. The specification of this carriage required that it should carry a useful load of 1½ ton on any road or gradient in a closed compartment of 60 cubic feet capacity. It weighs in running order 3 tons, and when light it weighs 35·4 cwt. The tank holds 220 gallons of water. A three-cylinder engine is used, the cylinder being of 4 inches diameter and $4\frac{11}{32}$ inches stroke, with a fixed cut-off at ⅞ths of the stroke. 250 revolutions give a speed of 11 miles per hour.

The Serpollet boiler is used and the Author examines its qualities for the present purpose at length, replying to adverse criticisms, which he thinks unfounded in regard to the boiler as now made. There is no valve between the boiler and the engine. Vaporization is almost instantaneous, and the steam supplied to the engine is regulated by varying the discharge of the feed-pump. During the four years since the latest improvements were made in this boiler, all the boilers made have lasted well and give every satisfaction.

The Author concludes with some remarks on the cost of these carriages and the expense of working them. He thinks that the present cost is excessive and that steam-carriages could be made for about a shilling per lb. of their total weight. Also, for practical usefulness, they should be capable of enduring a service of 180,000 miles at least. Experience shows that the coal consumption on a fair level road will be about 2¾ lbs. per ton-mile. An estimate is made showing that a steam-carriage with 1 ton of useful load and ½ ton of coal and water, itself weighing 1½ ton, would cost 16*s.* 9*d.* for a day's run of 62 miles, or about 2*s.* less, if running empty. This includes interest and depreciation. It is thought that on this basis a service of steam-carriages for the distribution of parcels and also for passenger traffic would be highly remunerative in many localities.

C. F. F.

Mechanical Traction on Tramways. By E. de Marchena.

(Mémoires et Compte rendu des travaux de la Société des Ingénieurs Civils, July, 1894, p. 58.)

This article, 125 pages in length, reviews the various methods in which mechanical traction has been successfully applied on tramways, examining the merits and defects of each system. In the first place the considerations are discussed which bear on the question of whether mechanical traction of any kind should be preferred to animal traction, and the important differences are pointed out between applying mechanical traction to a new line and to one already working with animals. The relative merits of

locomotives independent of the passenger cars, and of cars carrying their own motors, are then discussed.

As regards the application of the power, the various systems are divided into two categories:—(1) Tramways in which the power is developed at a central station and transmitted along the line direct to the cars without storage; and (2) Tramways in which each car or train carries with it a supply of energy sufficient for its journey. In the first category are found the endless-rope system and all the electric systems except that in which accumulators are used.

The endless-rope system is dealt with rather briefly, and very meagre data are given of the working of the system in America, where alone it can be said to have had its full development. Electrical traction is dealt with much more adequately; the cost of construction and of working both in America and in Europe is quoted from the best recent examples. The systems noticed in the second category are:—(1) The electric systems with accumulators; (2) Traction by compressed-air motors; and (3) Steam-traction. Other systems have been tried and many others proposed, but none have received the sanction of prolonged practical experience.

There are only three electric-accumulator tramways now at work in Europe. Particulars are given of each of them. Three installations of the Mékarski compressed-air system are also described, and the working of the system is explained in considerable detail. The Author concludes that this system shares with the electric accumulator the advantages of being absolutely unobjectionable in the streets of a populous town, while it is much more economical, and that, where any form of steam-engine is objected to, it may often be applied advantageously.

Under the head of steam-traction, the ordinary locomotive, as applied to tramway use, is first discussed, and particulars of two steam-tramways, viz., those at St. Etienne and at Geneva, are given. The experiment is also described which the northern tramway of Paris is making with the Serpollet water-tube boiler. The fireless locomotive is then dealt with at considerable length. The theory of its working is explained and the limits of its usefulness. The cost of equipment and working is analysed, and particulars are given of five installations. The conclusion arrived at is that, as compared with ordinary locomotives, the fireless locomotive system is about equal in first cost and is superior in working cost, there being a saving both in maintenance and in fuel, and, in certain cases, in wages. One case is quoted in which locomotives of both kinds, worked simultaneously on the same line, and the fireless engines proved the more economical, as well as being less objectionable.

A brief notice is given of other experimental systems, including that of Honigmann, in which a steam-engine and boiler are used, the furnace being replaced by a concentrated solution of soda into which the exhaust steam passes and raises the temperature of the

solution by its absorption. The ammonia-engine and the gas-engine are also alluded to.

In a concluding chapter the various items of cost are summarised for the various systems and average figures given, under the various heads, referred to the car-kilometer. For instance, the interest on capital cost of fixed machinery and rolling stock, allowing for amortization in ten years, is given as follows:—

	Per Car-Mile (Car of 50 Seats).
Compressed air	1·6*d.* to 1·9*d.*
Electric systems	1·3*d.* „ 1·6*d.*
Fireless locomotive	0·8*d.* „ 1·1*d.*

These figures have been calculated for an average installation, and are to be taken as correct relatively rather than absolutely.

In regard to fuel and oil, the following figures may be quoted (coal being supposed to cost 24*s.* per ton):—

	Per Car-Mile.
Compressed air	1·8*d.* to 1·9*d.*
Fireless locomotive and electric accumulators	1·3*d.* „ 1·4*d.*
Electric traction (overhead wires)	1·0*d.* „ 1·1*d.*

C. F. F.

A New Method of Rail-Fastening. By — Diechmann.

(Verhandlungen des Vereins für Eisenbahnkunde, 1894, p. 108.)

This method consists of fastening the rail to the sleeper by means of a spike in two portions, the main portion and the secondary portion. The main portion resembles the spike ordinarily used with the exception that in its back it has a recess slightly curved outwards, that extends to within a short distance of the bottom, and into which the secondary portion is driven. The secondary portion being longer than the recess, on being driven its end forms a curve in the timber, and by this means it is impossible for the spike to get loose. For very hard timber two of the secondary portions can be used, one on each side of the main portion, and the head of the main portion can be provided with a screw and nut. The main portion cannot be drawn out until the secondary portions have been drawn. Experiments which have been made show that the secondary spikes can be drawn—according to the material used in their manufacture—from sixteen to twenty times before they become useless.

Several of the German Railways have laid down trial lengths fitted up with the fastening, which is an invention of Messrs. Lorenz of Karlsruhe.

The Paper is accompanied by plans and sections.

J. A. T.

The Lichtenfels Fastening for Rails in Iron Permanent Way.

(Stahl und Eisen, August, 1894, p. 719.)

This noteworthy invention for securing rails to metallic transverse sleepers, which has been patented by Professor Lichtenfels of the Technical High School, Brünn, consists of a wedge-shaped bed-plate placed between the rail and the sleeper, two clip-plates of slightly different size, and two bolts (each of which passes through slots in the bed-plate and the sleeper on either side of the rail, and carries one of the two clip-plates) with nuts and split-washers. By the use of this contrivance, six alterations of gauge, varying from 0·157 to 0·944 inch (4 to 24 millimetres), are obtainable.

On each face of the bed-plate there are two projections, the form of which varies with that of the foot of the rail. Projections on the same face of the plate differ in width by 0·314 inch (8 millimetres), while each is of the same width as the one on the other face to which it is diagonally opposite. The projections on the lower surface fit into the slots cut in the sleeper in such a way that the bed-plate rests secure and immovable upon it without requiring to be bolted. Owing to the difference of width of the projections, a reversal of the surfaces of the bed-plate causes a shifting of the foot of the rail by about 0·314 inch. The amount of the alteration of gauge is indicated by the sum of figures visible on the two bed-plates resting upon the sleeper.

The clip-plates are accurately fitted between the foot of the rail and the projections on the bed-plate, and are so formed as to bear truly on their surfaces, while the boss or tongue below the wings of the clip-plates fits into the slots in the bed-plate; and, even when not screwed up, they lie quite securely in the intended position. The clip-plates differ in width by about 0·157 inch (4 millimetres) and can be mutually exchanged, a shifting of the rail by the same amount being thus obtainable. A figure on the clip-plate indicates the amount of displacement that can be effected in this way. By the combination of the various positions of the bed-plates with those of the clip-plates, seven different gauges can be obtained, the amount of alteration above the normal gauge being equal to the sum of the figures visible on both the bed-plates and the clip-plates used on the sleeper.

The total weight of the Lichtenfels fastener is 12·16 lbs., and the inventor uses in connection with it sleepers of Heindl pattern.

The fastener is especially worthy of notice on account of the great resistance which it offers to movements of the rails in the direction of their length. A displacement or distortion of any part of the arrangement is quite impossible. The bearing parts of the clip-plates are possessed of very great strength. The fewness of the pieces of which the fastener consists is an important feature. The laying and maintenance of the permanent way is a simple matter. The numbering of the bed and clip-plates renders

mistakes in altering the gauge almost inconceivable. Small clip-plates and bed-plates may be rolled. The weight of the contrivance is comparatively great, and the cost is on that account somewhat higher than that of fasteners of lighter weight. This, however, cannot be a serious objection to the system if its theoretical merits are confirmed by its efficiency in practice.

The notice of this fastener is illustrated with three sections.

A. H. C.

Experiments on the Evaporation in Locomotive-Boilers made in the Workshops of the Paris, Lyons and Mediterranean Railway Company. By A. Henry.

(Annales des Mines, Ninth Series, vol. vi., 1894, p. 119.)

A large amount of labour has been bestowed upon the experiments, calculations and tables described in these 116 pages. The first object of the experimenter was to ascertain the correct length for tubes in a locomotive boiler in relation to both the maximum steaming power and economy. It is well known that any increase in the length of tubes tends to increase the economy, but limits the power of the boiler. But the questions to be answered were: Is it worth while to thus increase the weight of a locomotive and diminish its maximum power, in order to obtain some economy of fuel? And, is it not preferable in many cases, such as express locomotives, to shorten the boiler, thus extending the maximum limit of its power? The trials were carried out in 1885–90, when various proportions and conditions were applied to this fixed experimental boiler, including differing amounts of draught, forms of fire-box, area of grate and length of tubes, and lastly an exhaustive inquiry into the proportions of internally-ribbed, or Serve, tubes. The steam-pressure was maintained at 142 lbs. per square inch. The tubes were of nine different lengths, varying from 23 feet to 6 feet 6¾ inches, but it was soon found that ordinary smooth tubes shorter than 9 feet 10 inches long had no practical interest. A blower was used to regulate the blast, and the form of grate, with 25 square feet of area, and smoke-box resembled the standard locomotives. Three kinds of arch in the fire-box were tested, two brick arches about 9 inches longer and shorter respectively than half the length of the grate, and a water arch of the usual Tenbrink pattern. Exact measurements were taken of the water evaporated and also of the good briquette fuel, including the moisture and ashes in the latter; the force of the blast; the temperature of gas in the smoke-box, for which purpose, after various trials, the Salleron pyrometer was used; the amount of carbonic acid, carbonic oxide and free oxygen in the smoke-box gases; and also the moisture carried off by the steam. The amount of arches carried through the tubes and the calorific power of the fuel were also ascertained.

The number of separate experiments made with smooth ordinary brass tubes of 1·97 inch outside diameter was eighty-one, including the various combinations of the following conditions: seven different lengths of tubes varying from 23 feet to 9 feet 10 inches, four different types of fire-box, three having an arch, and three different amounts of chimney draught, 25, 45 and 75 millimetres, or 1, $1\frac{3}{4}$ and 3 inches of water, $1\frac{3}{4}$ inch having been found in practice to be the draught corresponding with the maximum continuous work of the locomotive, and 3 inches to be the highest draught attained for short periods. Each experiment lasted three hours, after about three-quarters of an hour had been spent in getting the specified conditions of each test into working order; and frequent observations were made to record its complete history. After each charge of fuel, air was admitted at the fire door to insure complete combustion, the amount being gradually reduced till at the end of one and a half minute the supply of air was cut off.

The elaborate results obtained are set forth in Tables and diagrams, and among their many characteristics the following may be noted. The rate of combustion is reduced by the introduction of an arch in the fire-box, this being most apparent with the long fire-brick arch. The rate of combustion is affected inversely by the length of the tubes, rising about 15 per cent. in passing from tubes 16 feet 5 inches to 9 feet 10 inches long. The rate of combustion falls 25–31 per cent. on decreasing the draught from $1\frac{3}{4}$ to 1 inch, and rises about 27–33 per cent. on increasing the draught from $1\frac{3}{4}$ to 3 inches. The amount of water evaporated per hour, or the power of the boiler, is greatest with tubes of 13 feet 2 inches long and attains its maximum with the Tenbrink arch. The amount of water evaporated per unit of fuel, or the economy of the boiler, is increased by the use of a long brick arch when the tubes are short. With tubes of average length and a draught of $1\frac{3}{4}$ inch the short brick-arch shows an advantage of 6 per cent., the long brick and Tenbrink arches 8 per cent., over the ordinary fire-box. With tubes of 9 feet 10 inches long this improvement amounts to 9 and 12 per cent. respectively. The economy increases but in a diminishing ratio as the tubes are lengthened. Tubes 16 feet 5 inches long are on an average 16 per cent. more economical than tubes 9 feet 10 inches long, but beyond this length the economy increases only slowly. On passing from tubes of 13 feet 1 inch to 16 feet 5 inches length, the economy increases about 5 per cent., and from 14 feet 9 inches to 16 feet 5 inches it amounts to only about 2 per cent. using an arch. The influence of draught upon the economy with boilers having an arch shows an increase of $1\frac{1}{2}$–3 per cent. on falling from $1\frac{3}{4}$ to 1 inch of draught, and a diminution of 3–4 per cent. on rising from $1\frac{3}{4}$ to 3 inches draught. The amount of ashes drawn through the tubes is proportional to the strength of draught, and with ordinary draughts the introduction of any kind of arch in the fire-box decreases this amount about 45 per cent. The value of the arch is also shown to lie in an improved combustion to the extent of 8 per cent. The influence of the water

arch and long brick arch upon the temperature of smoke-box gases is shown to be the same, namely, a reduction of 4–6 per cent. in the number of degrees of temperature below that of a boiler having no arch. The true economy of the boiler, or the proportion of heat of combustion actually transferred into the dry steam, decreases rapidly with any shortening of the tubes. When the tubes were shortened from 16 feet 5 inches to 9 feet 10 inches, this economy decreased 18 per cent. with the ordinary fire-box and 15 per cent. with any kind of arch. The influence of a reduction of grate area was ascertained by repeating the whole of the eighty-one experiments with one quarter of the grate bricked up, and again with half the grate. In the former set of tests the rate of combustion was decreased 32 per cent. with 1 inch draught, 27·5 per cent. with $1\frac{3}{4}$ inch draught, and 25 per cent. with 3 inches draught. A reduction in the number of tubes does not affect the economy, but the power of the boiler is diminished in the same ratio.

The general conclusions from these experiments are: firstly, a large grate area is advantageous; secondly, the water arch and short brick arch are each of considerable value to the boiler, the former being somewhat superior to the latter but more troublesome to maintain, especially with large fires; thirdly, the most suitable length of tube is between 13 feet 1 inch and 14 feet 9 inches, which assures the maximum duty while it gives also a good economy (special conditions in the locomotive as to weight or power may justify lengths varying from 9 feet 10 inches to 16 feet 5 inches), but these limits should never be surpassed; fourthly, the regulation of the draught is the best means of giving elasticity to the power of the locomotive; fifthly, the number of tubes should be made as large as possible.

A number of experiments were subsequently made on six boilers of varying dimensions intended for service. These had iron tubes, and the principal conclusions drawn were, that boilers carrying a pressure of 213 lbs. per square inch and having iron tubes slightly dirty (*entartrés*) show the following losses when compared with boilers carrying 142 lbs. per square inch, and having tubes of clean copper. Firstly, a reduction of 1–4 per cent. in the amount of fuel burned; secondly, a loss of 4–6 per cent. in evaporative power per unit of fuel. Attention is also drawn to the important fact that the whole of the foregoing results are the best which it is possible to attain in practice.

Mr. Henry next turned his attention to the Serve tubes furnished with eight internal ribs, which largely increase the surface of tube in contact with the hot gases. During a preliminary trial of a set of these tubes in a goods engine, the difficulty of keeping them clear was solved by blowing steam through each tube, and the occasional application of a triangular rake. The results of this trial were so encouraging that a series of one hundred experiments was carried out with the same care as was given to the previous experiments on ordinary tubes. The diameter, length, arch and draught were each varied in turn, and the results measured and tabulated.

From these two elaborate series of tests an exhaustive analysis follows, comparing ordinary with ribbed tubes made of brass having equal draught, and each set having its length of maximum efficiency, viz.:—

	Inches in Diameter.
13 feet 1 inch for ordinary tubes	1·97
8 „ 2 inches for ribbed „	1·97
9 „ 10 „ „ „	2·56

The following results are gathered from an examination of these Tables and diagrams. On changing from ordinary to ribbed tubes of the same diameter, 1·97 inch, the activity of combustion is reduced 9–10 per cent. with a brick arch and 7–10 per cent. with the Tenbrink arch. By introducing the larger ribbed tubes, however, the activity of combustion is increased 5–6 per cent. with the brick arch, and 1–2 per cent. with the Tenbrink arch, compared with the ordinary tubes. The evaporative power of the boiler having a brick arch is reduced 7 per cent. with a draught of 1 inch, and 5 per cent. with a draught of 3 inches, when ribbed tubes take the place of ordinary tubes of the same diameter (1·97 inch). But if ribbed tubes of 2·56 inches diameter take the place of these ordinary tubes, the evaporative power is increased 5 per cent. with a draught of 1 inch, and 3 per cent. with a draught of 3 inches. The efficiency, or amount of water evaporated per unit of coal, is increased 1 per cent. with a draught of 1 inch, and 4–5 per cent. with a draught of 3 inches on the substitution of ribbed tubes of the same diameter; but with the larger diameter of ribbed tubes a slight loss of efficiency occurs, compared with the smooth tubes. The ashes deposited in the tubes and smoke-box when using ribbed tubes of either diameter and a draught of 1 inch amount to about double the deposit when using ordinary tubes, but this proportion rapidly decreases with an increase of draught. The completeness of combustion is not sensibly influenced by either the form or dimensions of the tubes. The temperature of the smoke-box gases is 13–18 per cent. lower with ribbed tubes than with ordinary tubes of the same diameter, either with the brick or water arch, and this difference increases as the draught becomes stronger. Ribbed tubes of 2·56 inches diameter and ordinary tubes of 1·97 inch diameter deliver the gases into the smoke-box at the same temperature when a brick arch is employed. With the Tenbrink water-arch and a draught of 1 inch this is also the case, but as the draught rises to 3 inches these gases are delivered into the smoke-box 6 per cent. cooler. The efficiency of the boiler considered as a heat engine is the same with the larger ribbed and with the smaller smooth tubes, but with the smaller ribbed tubes this efficiency is increased 3–5 per cent. In the latter case 8–14 per cent. less heat-units are carried away to the chimney by the burnt gases than when smooth tubes are used. The general evaporative efficiency of the boiler with either of the three sets of tubes was the same.

The following conclusions may be drawn from these briefly summarised results. The employment of Serve or ribbed tubes

permits a considerable shortening of the boiler without diminishing its duty or power. In changing from smooth tubes 1·97 inch diameter, and 13 feet 1 inch long, to ribbed tubes of the same diameter 8 feet 2 inches long, the total diminution of weight of this experimental boiler in working order was 2·156 tons; and in changing to ribbed tubes 2·56 inches diameter and 9 feet 10 inches long the reduction in weight was 1·205 ton. It is pointed out, however, that the maximum results obtained by these experiments are not realized in practice after either the smooth or the ribbed tubes have been in service for some time.

The Paris, Lyons and Mediterranean Company has now in service a considerable number of locomotives furnished with ribbed steel tubes 2·56 inches diameter. Any comparison between these and the more recently manufactured brass ribbed tubes has not yet been ascertained in practice. In consequence of the experiments herein described, the railway company has adopted iron ribbed tubes, with a brick arch in the fire-box, for all new or rebuilt locomotives during the last three years. In some of the rebuilt machines tubes 1·97 inch diameter 8 feet 2 inches long have been placed in order to retain the old tube plates, which were drilled for this size of tube. But in some cases the volume of water in the barrel has been found somewhat small, and better results have been obtained on similar boilers by replacing the tubes of 1·97 inch diameter 8 feet 2 inches long by others 2·56 inches diameter and 11 feet long. This has been done in rebuilding the express engines of the 1879 type.

In new locomotives the usual dimensions of tube adopted are 2·56 inches diameter and 9 feet 10 inches long.

E. W.

On Hydraulic Buffers for Railways. By — Sarre.

(Verhandlungen des Vereins für Eisenbahnkunde, 1894, p. 37.)

The Author briefly describes the hydraulic buffers which have been erected at the Potsdam Station, in Berlin, and at the Strasburg Station. He claims that these buffers have combined the advantages of the Webb and Langley systems, and have besides their piston-rods bound horizontally by means of a cross-bearer guided in a slide-bar.

The Strasburg buffer, which is similar in most respects to the Berlin buffers, exhibits the following peculiarities:—

(1) In the pipe which conveys the water from the back of the cylinder to the front, a valve, for the purpose of increasing the water-supply or pressure at the front, is fixed, which opens slightly under an additional pressure of 45 atmospheres, and opens entirely by an additional pressure of 50 atmospheres.

(2) The compression-cylinder is braced.

The buffer is fixed by means of two powerful sloping braces; in

each brace a link of carefully calculated dimensions is placed, which is broken when a train arrives at the buffers with an excessive speed, so that the compression-cylinder then becomes free and is pushed away from the assailing train, and, consequently, the least possible damage is caused. Under the cylinders the formation is ballasted with sand to a height of 1·64 foot above the rail-level, into which the wheels of an assailing train will run, by this means increasing the brake-power of the train.

The Author enters very fully into an explanation of the principles which have led to the adoption of hydraulic buffers, and proves the following formulas:—

If W is the resistance which the incoming train experiences at the buffers, C a constant, c the speed of the train in metres per second, F the area of the compression cylinders, γ the specific gravity of the fluid, g the acceleration by a free fall, f the area of the pipes in which the fluid escapes from the back of the cylinders into the forward parts, w the speed with which the water flows through the escape-pipes in metres per second, and p the additional compression in the back cylinder-space on the unit of the piston-surface in kilograms per square centimetre, the resistance is—

$$\left.\begin{aligned} W &= p \cdot F \\ \text{and } p &= C \cdot \frac{w^2}{20\,g} \cdot \gamma, \end{aligned}\right\} \quad . \quad . \quad . \quad (1)$$

and since

$$w = c \cdot \frac{F}{f},$$

$$W = C \cdot \frac{c^2 \cdot F^3 \gamma}{20\,g \cdot f^2} \text{ kilograms} \quad . \quad . \quad (2)$$

(in which F and f are in square centimetres).

In order to design a hydraulic buffer, it is necessary for the determination of the dimensions F and f, to know the values of c and W. Hitherto the buffers have been designed to stop a train weighing from 170 to 200 tons, and travelling at a maximum speed of 9 miles an hour. If such a train were to assail the buffers at a greater speed, the collision would be violent. If, however, in designing a buffer, a maximum speed of 18 miles an hour were taken into consideration, great difficulties would be encountered.

Let G = the weight of the train,
l = the path of the piston,

then

$$W\,l = \frac{G \cdot c^2}{2\,g} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$l = \frac{G \cdot c^2}{2\,g\,W} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

If G be taken equal to 200 tons, W = 20 tons, and $c = 13 \cdot 5$ feet per second (9 miles an hour) and $27 \cdot 0$ feet per second (18 miles an hour) respectively, then $l = 28 \cdot 87$ feet, or $115 \cdot 48$ feet It is therefore necessary to raise the value of W; and to find its highest permissible value, consideration must be taken to find the limit above which damage would result to the passengers. The Author then considers very fully the effect of the impact at the moment of collision on the passenger in relation to the length of the piston-path, and arrives at the following formula:—

$$l = \frac{c^2 e}{2 g h},$$

in which e is the width of a compartment (= 6·56 feet at the most), and h the height which a body must fall in order to attain the relative speed at the moment of impact.

The following Tables are given showing the values of W, l, and s (s = the length run by the train after its impact with the buffers before the passenger is thrown forward) for an incoming train weighing 200 tons, at the speeds of 11·84 feet per second (= 8 miles an hour) and of 27·33 feet per second (= 18·63 miles an hour).

c = 11·84 feet per second.

h =	0·33	0·66	0·98	1·64	3·28	4·92	feet.
W =	10	20	30	50	100	150	tons.
l =	43·64	21·65	14·44	8·86	4·26	2·90	feet.
s =	27·23	17·39	13·12	8·53	4·26	2·29	feet.

c = 27·33 feet per second.

h =	0·33	0·66	0·98	1·64	3·28	4·92	9·48	feet.
W =	10	20	30	50	100	150	289	tons.
l =	237·20	118·40	79·08	47·57	23·62	15·75	8·20	feet.
s =	71·53	48·56	38·38	28·22	18·04	13·78	7·87	feet.

From the latter Table it will be seen that by a piston-path of 8·2 feet, the length hitherto adopted, the collision would have the same effect on the passengers as a free fall of 9·48 feet. The Author states that in order to bring a train weighing 200 tons to a stand, without injury to the passengers, having a speed at the moment of impact of 18·63 miles an hour, the length of the piston-path should be 20 feet.

The Strasburg buffer has a piston-path of 8·2 feet, and is designed to bring a train weighing 200 tons, at a speed at the moment of impact of 8 miles an hour, to a stand without injury to the passengers. The resistance amounts to 50 tons, and the compression in the cylinders to about 40 atmospheres. If the train entered at double this speed, the resistance would be four times as great, and serious danger would menace the passengers; in order to reduce this the valve mentioned previously is introduced, and it opens immediately the pressure of 45 atmospheres is attained, and, consequently, a too strong increase of the resistance

is rendered impossible. The link in the braces is broken when the resistance attains to about 143 tons.

The Author concludes by stating that the piston-paths should have a length of about 20 feet in order that the buffers shall have greater efficiency: the cost thereby would be raised considerably; but owing to the fact that the number of terminal lines into which express trains enter is comparatively small, it is not of so much importance, and if the buffers are built according to a proposal recently brought forward, to have the compression-cylinder, not as heretofore in the buffer line of the locomotive, but near the rails with the train working on the piston-rods, no loss of length of platform need ensue.

The Paper is accompanied by a plan and sections of the Strasburg buffer.

J. A. T.

Engineering Workshops in the United States.

By Eug. François, Engineer to the Cockerill Society, Seraing.

(Revue Universelle des Mines et de la Métallurgie, July, 1894, p. 1.)

During a recent visit to the United States, the Author inspected several engineering workshops, devoting his attention almost exclusively to determining how the Americans, with labour two to three times more costly than in Belgium, were able to sell their machinery, more particularly stationary and locomotive engines, at prices practically the same as those asked for in his own country.

In this Paper, he discusses the subject under the following heads:—

(1) The simplicity and uniformity characterising the machines constructed, and the more general use of cheap materials.

(2) Tools employed in the shops.

(3) The methodical organization of the work.

In some preliminary remarks the Author observes that the market to be supplied is of wide extent and the demands very great. Specialization is, consequently, much practised and the production is enormous. The Baldwin Locomotive Works at Philadelphia, for example, employs 5,000 men and builds 1,000 locomotives per annum. The Westinghouse Machine Company of Alleghany City, Pittsburg, sends annually into the market about 600 engines of various sizes, representing altogether 36,000 HP., and employs only 250 men, among whom there are scarcely a dozen fitters and only two or three draughtsmen. The Worthington Hydraulic Works, Brooklyn, employs 1,500 men, and tests every day about thirty pumps of all kinds and sizes, from toys with a steam cylinder only 2 inches in diameter up to machines capable of raising 13,000,000 gallons per twenty-four hours. And, finally, the E. P. Allis Reliance Works, Milwaukee, employs 2,000 men, constructs 300 engines per annum for driving, blowing, rolling,

pumping, winding and other purposes, and has the reputation of being able to despatch an engine of ordinary type within eighteen hours of the receipt of an order for it.

Great sacrifices are made by Americans in order to secure simplicity of construction and reduction of manual labour. They possess not only the fastest express train in regular service, but also the locomotive that has attained the greatest speed per measured mile. The Author enumerates the characteristic features of the American locomotive, and passes then to other examples of simplicity of construction and cheapness of production, notably the Worthington pumps and the blowing-engines made at the Allis works.

Castings are much less costly than forgings, and in the United States a more general use of the former is made than in Europe. At the Allis works the resistance of castings to fracture by bending is at least 570 lbs. per square inch. The castings are generally moulded in greensand, the cores alone being dry. Moulding machines are much used. The Author describes the method of cleaning small castings in a revolving barrel. Pieces with cores are avoided as much as possible, sections of channel, cross and tee shape being preferred.

The fires of an American forge are usually connected with one main stack provided with a fan to exhaust the smoke.

The superiority of American machine-tools over those used in Belgium is indisputable. They are driven at greater speed, and, being as automatic as possible, one man can often attend to several of them. There are relatively more machines for continuous work, such as lathes, boring-machines and drilling-machines; while the number employed for intermittent work, such as mortising, planing and filing, is reduced to a minimum. The Author indicates the peculiarities of American lathes, drilling machines and other machine-tools. Tapping by machinery is a general practice in the United States, the operation being much more speedy and accurate than hand-tapping. Various other features of the shops are specified.

Under the head of Organization of Work, the Author describes the adjustable drawing-boards used in the offices, the methodical arrangement and storing of plans and patterns so that they may be readily found when required, and the systematic delivery, sharpening and collection of machine-tools. He states that the use of instruments for precise measurement with micrometer screws has become very common in the shops. Communication between the different members of the staff is greatly facilitated by the employment of telephones. In certain workshops there are ingenious arrangements for regulating the entrance and exit of the workmen in such a way as to obviate the disorder and loss of time that occur elsewhere at the beginning and end of each interval of work.

The interchangeability of parts, centralization in the production of steam and the subdivision of the motive power between a certain

number of motors, are other characteristics of American workshops. At the Baldwin, Worthington, and other works, there are two or three Westinghouse motors in one and the same shop.

In conclusion, the Author remarks that, although the American shops are superior to the European in certain respects, it is possible to exaggerate their merits.

The Paper is illustrated with numerous figures.

A. H. C.

Optical Properties of Lighthouse Apparatus. By C. Ribière.

(Annales des Ponts et Chaussées, August, 1894, p. 190.)

This Paper contains a comparison of the plano-convex form of lens with the later forms introduced by Mr. C. A. Stevenson, namely, the spherical refractor and the equiangular lens.

Fresnel and Allard developed formulas which are sufficient for calculating all the elements of a plano-convex apparatus, but these formulas are not adapted for making the comparison in question, and the Author establishes new ones.

The properties dealt with are those of divergence, chromatic dispersion, and loss by reflection. In each case a mathematical formula is proved, and from it a Table is calculated for various angles of incidence extending to 40° from the centre of the lens, for each of the three forms of lens mentioned above.

It is shown that up to an angle of 30° the ordinary formula for a simple lens $\frac{1}{p} + \frac{1}{p^1} = \frac{1}{f}$ may be applied without serious error to the plano-convex stepped lens.

A new method is also developed for calculating the profile of a plano-convex lens, and a Table for facilitating the calculation is given. A simpler method is also given for catadioptric rings, and the question is discussed as to the point at which their use becomes advantageous.

The conclusions arrived at may be briefly summarised as follows:—

The plano-convex lens of Fresnel has a coefficient of optical divergence which increases with the distance from the centre, but, owing to the simultaneous increase of the distance between the luminous source and the point of incidence on the lens, the real divergence is practically constant. Constant divergence in all parts of the lens being the desideratum, there is no motive for substituting other forms which realize it less completely, and which are not capable of the same precision in manufacture and mounting. The spherical form is particularly defective in the large divergence it gives at points remote from the centre of the lens. In regard to chromatic dispersion the spherical form is much inferior to the other two forms considered. The equiangular

lens is slightly better than the plano-convex. At 30° from the axis, for instance, the equiangular lens gives a divergence from this cause of 37′, the plano-convex 40′, and the spherical 52′. The losses by reflection are of small importance. The equiangular and plano-convex are about equal in this respect; the spherical is superior up to 25°, but above that angle the loss on emergence increases rapidly, the reflection for some rays becoming total at about 40°.

The Author, on the whole, sees no ground for giving up the Fresnel type of lens.

In regard to catadioptric rings he thinks there is no advantage in bringing them nearer to the centre of the lens than 30°, seeing that any slight error in the profile or adjustment produces double the effect in them that a similar error would produce with one of the refracting elements of the lens. It is not rare to find that the divergences due to want of accuracy in the apparatus are much greater than any that could arise theoretically from the superiority of one form of apparatus to another, and, therefore, the form which admits of the best construction is to be preferred.

C. F. F.

Records of the Ministry of Industry and Public Works of Chile, January to June, 1893.

(Government Report. Santiago de Chile, 1894.)

This biennial publication records in successive Minutes all ministerial decrees and other Acts relating to public works in the Republic of Chili, such as railways, roads, harbours, bridges, schools, &c. When these are executed at the expense of the State, summaries are given of the number of officers and men employed upon them, the monthly advance made with the work, and the sums expended; when executed by companies, or private individuals, the amount of official supervision is recorded. A catalogue of ministerial decrees is also published under which numerous concessions and patent or other rights were granted, or transferred; and the monthly reports, addressed to the Director-General of Public Works by the engineers in charge of works, are registered.

The sums expended under the supreme control of the Director-General of State Railways during the year 1892 amounted to £1,992,450, and the expenditure sanctioned by the Minister for the year 1893 to £2,293,254.

The majority of the railways in construction by the State during the first six months of the year 1893 are shown to have consisted of short lines, mostly branches from the main trunk lines, connecting inland towns with harbours on the Pacific coast; and monthly progress is reported on the following, some of which are

[1] The original is in the Library of the Inst. C.E.

now open to traffic. A distance along the coast of about 1,200 miles separates the most northerly from the most southerly of these railways:—

Vallenar to the seaport of Huasco (opened to traffic July, 1893).
Osorno to Pichi-Ropulli (works in active progress).
Pichi-Ropulli to seaport of Valdivia (works in active progress).
Palmilla to Alcones, and Talca to seaport of Constitucion (partly open to traffic).
Santiago (the capital) to Melipilla (now open to traffic).
Victoria to Temues (now open to traffic).
Parral to Canquenes (works in active progress).
Coigüe to Mulchén (progress slow).
Chañaral (now open to traffic).
Vilos to Illapal and Salamanca (progress slow).
Calera to La Ligua y Cabildo (part open to traffic).

Railway concessions were also granted during the same period from Peumo to El Manzano; from Temues to the river-port of Carahue, passing by the City of Nueva Imperial; from Tacna to San Francisco (an extension of the Arica-Tacna railway); and from the nitrate field of Atacama to the Taltal railway at Refresco.

The Ministry of Public Works publishes also as Excerpta from vol. xv. of the same publication, some strong evidence in support of a projected harbour and docks at Constitucion, a town of 7,000 inhabitants at the mouth of the River Maule, which is situated between the ports of Valparaiso and Talcahuano. The Republic of Chili has an extent of coast on the Pacific of about 2,500 miles; the distance by sea between Valparaiso and Talcahuano is only 256 miles, but these two ports are at present the only available outlets for the mercantile produce supplied by fifteen provinces, with a superficial area exceeding that of England, and a population (at the census of 1885) of 2,286,587 souls, or more than three quarters of the whole population of the Republic.

Constitucion lies 155 miles south of Valparaiso and 101 miles north of Talcahuano, in 35° 20′ S. lat., the centre of the most fertile part of the country, extensively cultivated with corn and vineyards, with a climate described as perpetual spring (mean temperature in summer 62·6° F., in winter 51·8° F., and the average of the whole year 57·2° F.); within a few miles of an extensive coalfield, and with a railway, now nearly completed, which at Talca, 57 miles from Constitucion, will connect with the trunk line running north to Valparaiso and Santiago, and south to Talcahuano, Arauco and Valdivia. If there were a good harbour at this point, it would become the natural outlet for the five provinces of Colchagua, Curicó, Talca, Linares and Maule, with an area of 17,200 square miles and a population of 716,402; who, it is estimated, annually consume 150,000 tons and supply surplus produce amounting to 200,000 tons suitable for export. It is stated that in 1892 the tonnage of cargo which entered and cleared at Valparaiso amounted to 2,864,030, and at Talcahuano to 1,640,404 tons; the exports and imports having been in both cases almost

evenly balanced. Constitucion also has a considerable coasting trade; in 1873 the total tonnage of ships entered and cleared exceeded 100,000 tons, but it has much diminished since that date. It is urged that such a harbour as is now proposed would yield an annual revenue to the State of £120,000 from Customs duties alone.

The population of these five provinces is the most industrious and hard-working in the whole Republic. Statistics are quoted showing that more than a quarter of the wine and spirits, cattle, horses, sheep, goats and pigs produced in Chili, more than one-half of all the wheat, maize and other corn crops, and 71 per cent. of the flax grown in the country, is the produce of these provinces, the most distant of which comes within 50 miles of Constitucion. The townspeople have been shipbuilders for the last hundred years; between 1886 and 1893 thirty vessels averaging 44 tons each, and 697 averaging 18 tons, issued from their building-yards, and amongst them were schooners, brigs and a frigate, of from 100 to 500 tons burthen.

The town is built on the banks of the River Maule, at about ⅔ mile from the ocean, from which it is separated and sheltered by the Cerro Mutrún, a projecting hill 300 feet in height. In front of the town, the river, which is navigable for a distance of 45 miles above Constitucion, expands into an estuary 765 yards in width, with a depth of water on the west or town-side, of 23 to 26 feet, excepting on the bar, upon which, at low tide, there are only 5½ feet of water. It is proposed to build moles on either side of the river so proportioned as to wash this bar away by natural scour.

Fronting the town there is an island, 1,300 yards long by 275 yards wide, which forms, with the shore of the mainland to which it runs parallel, a channel 130 to 160 yards in width. It is proposed to close the upper end of this channel and, by dredging and surrounding it with retaining walls, to convert it into a basin, or wet dock, of a capacity sufficient to float a very considerable number of ships. The building of the harbour in this sheltered position will offer little difficulty, and, when completed, ships of any draught will be able to enter it and anchor within the mouth of the river.

The studies have been made by Mr. Camilo de Cordemoy, naval engineer and adviser to the Chilian Government. He estimates the total cost at 4,000,000 dollars, of which he reckons that purchases made in Europe will absorb a considerable part, and that on that portion the loss by exchange will amount to 50 per cent. It is therefore impossible to convert this figure with any precision into English money. A plan of the harbour accompanies this publication.

O. C. D. R.

Friction-Rollers.

By C. L. Crandall, M. Am. Soc. C.E., and A. Marston, Assoc. M. Am. Soc. C.E.

(Transactions of the American Society of Civil Engineers, August, 1894, p. 99.)

Experiments were made to determine the friction of small rollers 1, 2, 3 and 4 inches diameter and $1\frac{1}{2}$ inch long, between plates which were $1\frac{1}{2}$ inch thick and 5 inches wide. The plates and rollers were made of cast-iron, wrought-iron and steel. Three horizontal plates were arranged in the testing machine, with two parallel rollers, one above and the other beneath the middle plate. A third roller steadied the latter but received little of the load. The pressure was applied above.

The following formulas were deduced from the experiments on cast-iron plates, by measuring with a spring-balance, the force required to produce sensible motion of the middle plate under varying pressures:—

$$\text{Friction per unit load} = \frac{0 \cdot 0063}{\sqrt{r}} \text{ for cast-iron rollers;}$$

$$\text{,, \quad ,,} \quad = \frac{0 \cdot 0120}{\sqrt{r}} \text{ for wrought-iron rollers;}$$

$$\text{,, \quad ,,} \quad = \frac{0 \cdot 0073}{\sqrt{r}} \text{ for steel sleepers;}$$

r being the radius of the roller in inches.

With wrought-iron plates these values are 13 per cent. greater, and with steel plates 13 per cent. smaller. The rollers were turned and the plates planed, but neither polished.

The second Author made experiments on the distribution of stresses in glass rollers by means of polarized light and investigated their amount theoretically. He further determined experimentally the safe load on rollers 1, 2, 3, 4, 6, 8, 10, 12, 14 and 16 inches in diameter respectively and 1 inch long. The bearing plates were 6 inches square and 0·9 inch thick. Rollers and plates were cut from the same steel plate; the former were polished and the latter planed. Using a test-piece 0·607 inch × 0·618 inch × $8\frac{1}{2}$ inches long, the elastic limit was 36,000 lbs. per square inch, the tensile strength 58,000 lbs. per square inch, the elongation in 5 inches 31 per cent., and the reduction of area of the fractured section 60 per cent.

The tests were made on a Olsen machine, capable of testing up to 50,000 lbs., at the Iowa State Agricultural College.

The result of these experiments gave as the crushing load (W) in lbs. per lineal inch

$$W = 880d,$$

d being the diameter of the roller in inches. A. W. B.

Air-Pumps. By F. H. Bailey, U.S. Navy.

(Journal of the American Society of Naval Engineers, August, 1894, p. 518.)

The amount of water to be pumped from a condenser by the air-pump is so small in comparison with the amount of air, that it need hardly be considered in determining the required displacement of the air-pump piston per minute. The amount of air depends largely upon leakage, which in turn depends upon the care with which the machinery is looked after. For this reason an independent air-pump is to be preferred to one driven by the main engine, since its speed can be varied to suit the necessities of the case. A good average value for independent air-pumps for men-of-war is 0·2 cubic foot displacement of air-pump piston per minute for each I.HP. This amount requires to be increased by 50 per cent. when the pump is attached to the engine. Leaky piston-rod stuffing-boxes usually admit most of the air entering the condenser. In the design of the pump, care should be taken to avoid any pockets in which air can collect without being expelled at each stroke. The most efficient pump is single-acting and vertical, in which the clearance can be kept full of water. The efficiency of a double-acting pump may be expected to begin falling off when a piston-speed of from 100 to 200 feet per minute, depending upon the length of the stroke, is exceeded. Vertical single-acting pumps give good results with piston-speeds of from 400 to 500 feet.

A good air-pump should maintain a vacuum within 1 inch of that due to the temperature of the condenser. With a temperature of air-pump discharge of 120°, 25·6 inches would be a good vacuum. The efficiency would probably not exceed 50 per cent., as about ½ inch of air would be required to raise the valves and overcome friction. Doubling the size of the pump would diminish the pressure of air above that required to lift the valves just one half, and the vacuum would be increased but ¼ inch. Similarly with a pump of half the capacity the vacuum would fall off but ½ inch. Too large a pump is more objectionable than too small a one, as, besides the unnecessary weight, space, and steam demanded, it is more irregular in its action; the valves fail to lift for some strokes, and then the pump is flooded. A capacity so small as $\frac{1}{15}$ cubic foot per minute per I.HP. has worked well in a single-acting vertical pump.

The velocity of flow through the bucket-valves should not exceed 1,000 feet per minute. Foot-valves should be of the same area as the bucket-valves and delivery valves larger. Several designs of independent air-pumps are described, and a Table is appended giving air-pump data from results of trials of U. S. vessels.

S. W. B.

Resistance of Floating Bodies with Flat Sides. By F. Fink.

(Der Civilingenieur, 1894, p. 399.)

The experiments already described by the Author[1] were on a series of pointed fore-parts of a ship, the angle made by the sloping sides varying by 6° from 6° to 90°. Those described in the present Paper are on similarly pointed after-parts. The opinions of various writers on the resistance of a body moving in a liquid are given in the Paper.

The experiments were made between the 15th October and 10th November, 1859, and from them the following surprising results were obtained.

(1) A floating body, formed by a parallelopiped with an after prismatic portion, drawn through water with a constant force, does not vary in velocity with a variation of the angle of the pointed after-portion so long as this angle is greater than 72°, *i.e.*, so long as the angle which the side of the pointed after-part makes with the side of the parallelopiped is greater than 54°.

(2) When the angle of the pointed after-portion is less than 72° the velocity increases as the angle is diminished; the total resistance of the body therefore diminishes.

Another series of experiments were made with a longer parallelopiped and the same pointed after-portions. The results obtained were in general the same as from the shorter parallelopiped.

The discontinuity in the resistance when the semi-angle of the hinder portion is 36°, is explained by the fact that when this angle is greater than 36° eddies are formed behind the ship. With sharper-pointed after-parts the water flows quietly past the end of the ship.

Another series of bodies with "flat punt" ends were experimented on, the angle of the inclined plane of the punt end varying by 12° from 12° to 90°. In this series, the resistance does not show any discontinuity between the angles 90° and 54°; between these angles it does not vary very much, and at 54° the resistance begins to diminish with diminution of the angle of the punt end.

The Paper is accompanied by six Tables of results, and by a sheet of drawings showing the results graphically, the forms of the ships experimented on, and the forms of the waves and eddies made.

A. S.

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[1] Der Civilingenieur, 1894, p. 116, and Minutes of Proceedings Inst. C.E., vol. cxvii. p. 423.

The Turbine-Propeller with Contractor. By C. Busley.

(Zeitschrift des Vereines deutscher Ingenieure, 1894, p. 1.)

The Elbe River Navigation Company has recently made extensive experiments with a turbine-propeller designed by Professor Zeuner of Dresden. A Henschel-Jonval axial turbine is placed at the stern of the ship in lieu of the screw-propeller. It may be thus described.

Upon the tail end of the shaft, in the position usually occupied by the screw, is a cylindrical boss carrying a number of curved blades which revolve with the shaft. Immediately in rear of them, and carried by a continuation of the boss which does not revolve being attached to the vessel, is another series of guide-blades so curved as to receive the water set in motion by the revolving blades and direct it sternwards. This fixed continuation of the boss is of the same diameter at its forward end as the portion to which the revolving-blades are attached, but tapers to a point aft with an O.G. curve. The whole is surrounded with a casing in which the forward blades revolve and to which the after ones are attached. The portion of the casing enclosing the revolving blades is cylindrical, but from the forward end of the fixed guides it commences to contract, and the area of the orifice at the stern end is much less than the area of the annulus through which the water enters. The casing and the boss are conterminous. The water issues from the outlet at a velocity considerably greater than that at which it passes the turbine. The ship is given a backward motion by dropping a curved tube before the outlet of the "contractor." The propeller may be placed partly above the water-level if a hood over the inlet of the tube makes the water enter below it, thus preventing the admission of air. Three steamers, "Elbfee," "Amsel," and "Sachsen," have been fitted with this propeller. The "Elbfee" is a little launch 41 feet long, 7½ feet broad, and having a mean draught of 29½ inches. It was driven originally by a 27-inch three-bladed screw, which was replaced by a 17¼-inch turbine, the orifice of the contractor being 13⅝ inches in diameter. It carried twenty revolving blades and sixteen fixed guides. The velocity of exit was calculated at 15·66 miles, and at 300 revolutions per minute 23 cubic feet of water passed through the apparatus per second. The results were as follow :—

——	Speed in Miles.	Revolutions.	I.HP.
Screw propeller	8·49	371	24·7
Turbine	8·82	303	22·5

The other two steamers were designed for the turbine-propeller

The dimensions of the "Amsel" are: length 38·6 feet, beam 8·2 feet, draught 1·6 foot. The speed is 7·83 miles. The "Sachsen" is 110 feet long, 12·5 feet broad, and has a draught of 25½ inches. There are two turbines, one on each side about amidships; the diameter of the turbines is 19¾ inches, with a 15-inch contractor. There are twenty revolving and thirteen fixed blades. The discharge is 40 cubic feet per second when running at 240 revolutions. The speed attained was 11·79 miles.

S. W. B.

Experiments with Rudder-Propellers.

(L'Industrie Électrique, 1894, p. 447.)

The Author describes some recent experiments made on the Seine on the electric propulsion of a barge by means of a propeller fixed on the rudder. The rudder in this system is made to carry the whole of the driving gear, including the motor and necessary reduction gear. In this way the rest of the barge is available for carrying cargo, &c. This rudder-propeller is attached to the stern-post of the barge in the same manner as an ordinary rudder, and is used in the same way for steering by hand. The propeller is placed on the end of a horizontal shaft running along the rudder-blade. At the end of this shaft nearest the barge is a gear-box containing a pair of bevel wheels which transmit the motion from a vertical shaft to which the armature of the motor is attached.

This gear runs in oil and has a reduction ratio of 37 to 11. The motor is fixed in a cast-iron case which forms the upper part of the rudder post. The cast iron, besides forming a magnetic screen, also prevents danger from sparks should the motor be overloaded. The armature is keyed direct to the vertical shaft, and its weight is supported magnetically. The whole of the rudder is made of sheet iron and designed to displace nearly its own weight of water. The propeller was designed by Mr. Galliot for a speed of 300 revolutions per minute, which give a motor speed of about 1,000 revolutions. This apparatus was fitted to a barge 125 feet long, weighing when loaded 178 tons. With a regular expenditure of 3,400 watts, or 4·6 HP., a speed of 1·9 mile per hour was obtained.

On the trials described the power was taken from storage batteries.

The article is illustrated by two cuts.

R. W. W.

The Influence of Temperature upon the Accuracy of Indicator-Springs.

(Bulletin de la Société Industrielle de Mulhouse, July, 1894, p. 269.)

To determine the power developed in a steam-engine with an indicator, the interior of the cylinder is placed in communication with one side of a small piston, the movements of which, caused by the pressure of the steam, are transmitted to a pencil in contact with a paper round a drum. The power indicated will thus be a function of the mean height of the diagram traced by the pencil on the paper, of the size of the engine cylinder, &c., and of the proportion between the displacement of the pencil and a corresponding difference in pressure of the steam. This proportion, depending upon the flexibility of the indicator spring, is usually determined by subjecting the indicator to a known pressure, and measuring the displacement of the pencil. The Author, however, considers this method unsatisfactory, and has substituted varying loads for pressures.

But to trace a line on the paper at starting, and another when the spring is loaded, and measure the distance between the two, was not sufficiently accurate for his purpose. He therefore divided the load into a certain number of equal parts, to each of which a line corresponded. The spaces between these lines should be practically the same. Errors due to friction of the spring were obviated by shaking the indicator each time before it traced a line. Two lines were drawn for each pressure, and the mean of the two taken. As, however, a spring when released may not return at once to its former position, but be accidentally deflected for a time, and the error pass unnoticed, the following precaution was adopted:—The positions of the pencil as the load increased were verified until the limit of weight had been attained; the spring was then gradually unloaded and tested in the reverse direction. The mean of the readings thus obtained ought, in the Author's opinion, to neutralize the effects of any disturbance in the spring while the indicator was at work. With a skilful operator the error should be less than one-tenth per cent.

Even, however, if a spring be carefully tested, the reading will not always be the same, because certain portions of the spiral only come into play with certain loads, and thus the reading of the scale may vary considerably. In transmitting movement to the pencil, the chief object seems hitherto to have been, to make the pencil trace a straight line instead of registering the delicate oscillations of the spring.

The influence of temperature upon the reading must not be overlooked. To determine it, the Author tested the same spring with the same loads, but at different temperatures, which were measured by a thermometer inside the indicator cylinder. Although the thermometer was separated from the spring by the indicator

piston, the temperature, owing to the conductivity of the metal, was practically uniform. By means of a current of hot air it was raised above 212° F.,—a temperature never, he believes, attained during an engine-test, seeing the short time the indicator is in contact with the steam, and the large radiating surfaces which carry off the heat. The Author proves by calculation that the flexibility of indicator springs increases in a given proportion with each degree rise in temperature. The chief difficulty in making these experiments is to determine the actual temperature of the spring at the moment of testing. This temperature once ascertained, accuracy can be secured, provided a sufficiently large number of observations are made. The Author, however, considers it sufficient in ordinary trials to test the springs cold, the resulting error being not more than 1½ per cent. to 2 per cent. This is compensated by the unavoidable errors in transmitting the variations in pressure on the piston of the engine to the indicator.[1]

B. D.

The Plane-Table Underground. By R. G. Brown.

(Engineering and Mining Journal, New York, vol. lviii., 1894, p. 128.)

The Author claims that the plane-table[2] may be advantageously used for mine surveying as a fairly accurate and very expeditious method of traverse running. The table used had a well-oiled pine top, 18 inches long by 14 inches wide. The alidade was of the usual compass-sights form. The paper, a long strip, was wound on a roller 1¼ inch in diameter underneath the table, passed up over the end of the table, which was rounded for the purpose, over the table and down round a second similar roller underneath the other end of the table. The rollers were each fitted with a small crank for turning, and a ratchet and pawl arrangement which served to stretch the paper tight in any position while allowing longitudinal motion. In conducting a survey with this instrument, the starting course is taken from the last theodolite course, or is transferred down the shaft by any of the usual methods. Dimensions of the workings are drawn in as the survey progresses, and on completion the work is traced on to the mine plan. Surveys conducted in this way will check very closely with theodolite lines over the same ground. The maximum error at the end of a traverse of 1,000 feet amounts to 2 feet, and two hours suffice for the dozen courses comprised.

B. H. B.

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[1] Professor Capper's Paper read before the British Association, Oxford, 1894, may also be referred to on the subject of the percentage of errors with indicator-springs, and their temperature, &c.—B. D.

[2] Minutes of Proceedings Inst. C.E., vol. xcii. p. 187.

The Bhaganwala Coalfield. By T. D. La Touche, B.A.

(Records of the Geological Survey of India, 1894, p. 16.)

This coalfield is situated near the eastern end of the Salt-Range, Punjab, and occupies a roughly triangular area of about 7 square miles in area. The fact of the existence of the coal here has been known since 1853; but it is only quite recently that a serious attempt has been made to open out the coal-seams. The distribution of coal is extremely irregular, the coal having originally been deposited in limited areas, or having been irregularly denuded subsequently to the deposition of the bed. Faults are neither numerous nor of great extent in the field. The coal, without doubt, belongs to the nummulitic group. It is remarkable, however, that it frequently contains specks and nests of fossil-resin, which is characteristic of the coals of cretaceous age in Assam. From the Author's calculations it appears that 88,480 tons of coal have been actually proved, and that a reasonable estimate of the coal available amounts to 1,000,000 tons. The conditions under which the coal is found, as regards roof and floor and thickness of the seam, are such that nearly the whole of the estimated amount should be easy of extraction, and the expenditure necessary to construct a branch line from Haranpur is amply justified.

The Paper is illustrated by a coloured geological map of the coalfield on a scale of 3 inches to the mile, by two sections across the coalfield, and by a view of the scarp above mine No. 7.

B. H. B.

The Ventilation of Mines and Centrifugal Ventilators. By Paul Habets.

(Revue Universelle des Mines et de la Métallurgie, July, 1894, p. 37.)

The Author remarks that the mathematical theory of centrifugal ventilators has really varied only in the form under which it has been presented by the numerous writers who have treated the subject, and mentions the principal theories that have been propounded since the publication of Combes' Treatise on Ventilation in the year 1839. He deals next at considerable length with the theory of gases and of their movement, discussing under that head the laws enunciated by Mariotte, Gay-Lussac and Dalton, Bernouilli's Theorem (published in the year 1738), &c. Passing then to the general theory of the ventilation of mines, he treats of the passage of air in a mine; the apparent and actual loss of charge; natural ventilation; the temperament of a mine, *i.e.*, the degree of difficulty attending its ventilation, resistance and equivalent orifice; apparent temperament and apparent equivalent

orifice; the proportionality of the loss of charge to the square of the discharge; and the work absorbed by the ventilation of a mine.

The Paper, which contains numerous mathematical formulas, is not concluded in this number.

A. H. C.

The Flue-Dust Condensers of the Freiberg Smelting Works.

By C. H. Bauer.

(Jahrbuch für das Berg- und Hüttenwesen im Konigreich Sachsen, 1894, p. 39.)

At the Freiberg Smelting Works a very extended system of condensing flues and chambers has been erected during the past thirty years for the purpose of diminishing the damage done to the woods and agricultural lands in the neighbourhood by the deleterious gases and vapours given off in the smelting operations which, in the year 1893, involved the treatment of about 45,000 tons of ores and products of different kinds containing lead, sulphur and arsenic. The sulphur from the pyritic ores is to a great extent utilized by conversion into sulphuric acid, for which purpose nine groups, comprising thirty lead chambers of 750,000 cubic feet total capacity, and concentrating works for the production of fuming and anhydrous sulphuric acid, have been provided; while the lead and other metallic vapours are collected in flues and condensing chambers of different kinds. The latter class of apparatus, as established at the larger of the two Freiberg smelting establishments, the Mulde Works and the improvements lately made in them, form the subject of the present Paper.

At the Mulde Works three systems of condensers are in use; the first of these, taking the gases from a group of eight lead-ore calciners, has a total length of 1,850 metres (about $1\frac{1}{8}$ mile), the first part, 1,296 metres long, being in brickwork, while in the second of 550 metres the flue is lined with lead. The draught is maintained by a chimney 42 metres high, assisted by a Guibal fan placed between the furnaces and the first condensing chamber. The second system, taking the fume from four blast furnaces and the whole of the lead and silver separating and refining departments, includes 198 metres of iron pipes, 514 metres of brick, and 245 metres of lead flue, the draught of the chimney 37 metres high and placed 15 metres above the bottom of the blast furnaces being also assisted by a Guibal fan. The third, and largest system, which is connected with one improving and three reverberatory smelting furnaces, four ore calciners, sixteen roasting clamps and a group of red arsenic-glass furnaces, extends in a single line for 915 metres to a chimney 58 metres high upon a base 76 metres above the reverberatory furnace-house, a branch of 602 metres supplied by two blast furnaces joining it at 211 metres from the

starting point. In this no artificial assistance is required for the draught, owing to the great height of the chimney, which reaches to an elevation of 430 feet above the lowest point of the works.

In 1890 it was decided to try the Freudenberg method, which has been in use for several years at Ems in Nassau, of dividing the flue into narrow parallel passages by thin sheet-iron diaphragms suspended from the roof, whereby a great increase of depositing surface is obtained with a comparatively small reduction of the cubic volume. For this purpose the portion of the brick flue in the second system of condensers was selected. It consists of twenty-one parallel arched chambers each 10 metres long, varying in breadth from 0·87 to 1·8 metre and 3 metres high to the crown of the arch, with 1,520 square metres surface, which was increased to 7,140 metres, or nearly fivefold, by the introduction of 2,810 square metres of thin iron plates in the space under the roof and half-way down to the floor, leaving about one-third of the area at the bottom open for the accumulating deposit. The upper plates in the arch are fixed permanently to iron-bars in the roof, at a distance of 12 centimetres apart, but the lower ones are suspended by hooks on cross bearers so that they can be shifted sideways for convenience in cleaning. Their distance apart is about 20 centimetres. This improvement, costing, inclusive of patent dues, £430, has worked very successfully; a comparison of the results obtained in 1891–93 with those of 1888–1890, or three years before and after the change, respectively showing that with an increase of 15 per cent. in the weight of materials smelted, that of the flue-dust saved had increased 45 per cent. as a whole, the deposit being largely augmented in the flues nearer the furnaces with a proportional diminution towards the chimney. In the flues with the plates this increase was as much as 82 per cent., while the deposit nearer the stack was lessened from 30 to 58 per cent.; the increase in weight being mainly due to the more perfect condensation of lead and arsenic vapour, and more particularly of the latter.

Notwithstanding these excellent results, the Freudenberg system is not considered by the Author as capable of any very extended application, partly on account of the limited range of temperature through which it is applicable, the gases must not be hotter than 70° C. nor cooled below 50° C., but more particularly because of the increased resistance to the current, which requires an increase of about 40 per cent. in the work of the ventilator to overcome it. The Guibal fan, 6 metres diameter and 1·1 metre wide, requires from 6 to 7 HP. to drive it, the speed varying from 65 to 85 revolutions per minute according to the number of furnaces at work. The gases leave it at 34 millimetres water-pressure, which is reduced to 3 millimetres at the end of the brick flues; the resistance due to the plates seems to be about equal to 20 millimetres. The cost of producing 1 millimetre pressure by the fan is £12 10*s*. per annum.

In the spring of 1893 the condensing area of the third system was increased by the addition of a group of chambers to the long

flue near the chimney on the hill. This is a rectangular building containing six parallel flues from 28 to 31 metres long, 3·15 metres wide and 3·3 metres high (10 square metres area), giving an extra length of 208 metres and 2,064 cubic metres more depositing space for the gases before reaching the stack, and is constructed on Monier's system of thin concrete walls stiffened by an internal lattice of iron-wire which has previously been applied to the building of lead fume condensers at Harzgerode and Friedrichshütte in Upper Silesia. The iron skeleton, consisting of frames made of rods 7 millimetres in diameter placed 7 centimetres apart and crossed by horizontal rods of 5 millimetres at the same distance, is imbedded in concrete forming a wall 50 millimetres thick, which is strengthened on the outer sides by buttresses of double that thickness projecting 80 centimetres at the bottom placed 2 metres apart. The concrete for the walls and arches is made of 1 part of cement to 3 of quartz in lumps 1 to 1·5 centimetres diameter and sand from the dressing floors, in proportions varying from equal parts to 7 of the former to 2 of the latter. For the foundations a concrete was used containing 6 parts of coarse metal slags, 3 of sand and 1 of cement. The finished wall carries 720 kilograms per square metre of distributed, or 360 kilograms of concentrated load, which is about equivalent in strength to timber of 28 millimetres or iron plate 9 millimetres thick. The inside of the flue is covered with an acid-proof coating whose composition is kept secret by the builders, the Monier Company of Berlin; the outside is protected by painting it with gas-tar.

The cost of the Monier chamber, apart from that of the connection, with the existing flue, has been £1,330. It was built in three-and-a-half months, May to August 1893, and was set to work in the latter month. Flues of the same size would have cost £1,500 in brickwork and £2,500 in lead. The loss of pressure owing to the large section is only about 2 millimetres, but for the same reason the deposit is comparatively small, being only 8·4 kilograms per 100 cubic metres per day, while that in the Freudenburg condenser is 57·2 kilograms.

In the year 1894 it is intended to double the size of the Monier chamber; the new flue is, however, to be in zigzag with free exposure on three sides so to have a greater cooling effect on the gases, and a fan will be added to assist the draught. With these additions the total condensing space at the works will be brought up to about 24,000 cubic metres.

The condensing arrangements in both works considered as forming a continuous line represents a flue of 40 square feet area about 5 miles long. The fume collected in 1893 amounted to 9·7 per cent. of the weight of the ore smelted, and contained 36,655 ozs. of silver, 1,658 tons of lead, 917 tons of arsenic, the value at the current tariff for the purchase of ores being £13,636. The sale of sulphuric acid in the same year was 14,409 tons, a further quantity being used in the production of 2,024 tons of copper sulphate.

Up to the end of 1893 the expenditure on arrangements for saving fume and gases and the prevention of smoke damage has been £235,389, of which £167,210 represents the cost of the sulphuric acid and arsenic works, and £68,179 that of the fume condensers for the smelting furnaces. Between 1855—when the principle of payment of damage was first admitted—and 1893 about £45,000 compensation has been given for injury to land and cattle from the fume, as much as £3,000 having been paid in one year, but during the last sixteen years the average has been only £184. At the present time it is estimated that about 20 per cent. of the flue-dust escapes condensing, but it is doubtful whether this could be materially reduced even with a considerable increase in the plant.

H. B.

A Compressed-Air Installation in a Freiberg Mine.

By R. Wengler.

(Jahrbuch für das Berg- und Hüttenwesen im Königreich Sachsen, 1894, p. 60.)

At the Alte Hoffnung Gottes Mine, near Freiberg, compressed air is used for driving machinery at several points underground at considerable distances from the source of power at the surface. The compressor, of an old "wet" form, the compressed air being cooled by direct injection of water, was made in 1883 for a mine now abandoned, and has been at work in the present place since 1887. It has steam- and air-cylinders of 380 millimetres in diameter and 640 millimetres stroke, and indicates at 20 revolutions per minute about 11·9 HP. in the former and 10·6 HP. in the latter, corresponding to a useful effect of 89 per cent. The delivery per hour at this speed is 170·6 cubic metres of air compressed to 5 atmospheres tension. Two old boilers having a joint capacity of 18·9 cubic metres are used as receivers. The supply-pipe of 76 millimetres bore is carried down the main shaft, an incline of 55°, to the twelfth level, a distance of between 500 and 600 metres, where it was first used in driving upon an adjacent lode with a Schram boring machine for a length of 200 metres, in order to connect with some workings advancing from the opposite direction, which were reached at about 400 metres from the shaft. The cost of this work was about 80*s.* per metre, or 33 per cent. dearer than hand-work, the difference being due to the price of the coal used by the compressor, which amounted to 20*s.* per metre. Subsequently the machine, supplemented by another made by the Duisburg Company, was employed in sinking below the twelfth level, when the method showed itself to greater advantage, the main shaft, measuring 6 by 2 metres, having been carried down 41·6 metres in fifty weeks at a less cost per metre of about 86*s.*, and a saving of three-and-a-quarter years' time over hand-work. The Duisburg machine being smaller and lighter than

Schram's is more easily handled; the corresponding dimensions of the two machines are:

—	Diameter.	Stroke.	Weight.	Strokes per Minute.	Air required.
	Millimetres.	Millimetres.	Kilograms.		Cubic Metre.
Schram's . . .	72·5	140	126	400	0·463
Duisburg . . .	56·0	120	55	500	0·285

With the former machine twelve holes and with the latter ten holes of an average depth of 90 centimetres each were bored in the shift of ten hours, about twenty minutes' actual boring time being required for each hole.

The stuff broken in the sinking was hoisted to the twelfth level by a small double-cylinder engine driven by compressed air. This was intended to be used compound, the cylinders being of unequal diameter, 150 and 100 millimetres; but subsequently full pressure was used in both without causing any irregularity when working with three atmospheres pressure. At 200 revolutions 150 kilograms can be lifted at a speed of 48 metres with a consumption of 1·2 cubic metre of air per minute. The average weight lifted was 132 kilograms, 92 kilograms of rock and 40 kilograms for the kibble, seventy-five kibbles being raised in the shift of ten hours, requiring about two hours' continuous use of the engine.

A third application of the power is in driving a rock-breaker at the cobbing-house adjoining the stamps. This is supplied by a 44-millimetre gas-pipe 370 metres long, taken off the shaft main at a point 49 metres vertically below the surface and carried along a level, which brings water to the wheels in the shaft for a length of about 350 yards to its mouth. This machine, which breaks per hour from 2½ to 3 tons of veinstuffs supplied in 3 to 6-inch lumps to a proper size for the stamp, is driven directly by a compressed-air engine of 160 millimetres diameter and 220 millimetres stroke, cutting off at 40 per cent. and making 200 revolutions per minute equal to 4·7 HP. indicated at four atmospheres pressure. In order to prevent the formation of ice in the exhaust, the air before entering the engine is passed through a receiver heated by external firing which raises the pressure one atmosphere. Old mine timber is used as fuel. The air-consumption per minute is 0·855 cubic metre. With this machine less than one-half of the labour is required than was necessary when hand-cobbing was used, and as the stuff is more regularly broken the duty of the stamps has been improved about 25 per cent.

The power remaining available from the surface compressor after providing for the uses specified above has been applied to a compressed-air locomotive for hauling the ore broken at different points in the mine at and above the fourth level to the shaft, a distance of about 1,000 metres. For this purpose a 50-millimetre

branch pipe is taken off the shaft main at the fourth level, 189 metres below the surface; but as the pressure of five atmospheres would not be high enough to enable the locomotive to carry a sufficient supply for the journey unless the reservoir were made unmanageably large, an intermediate compressor is used which raises the pressure to twelve and eighteen atmospheres by two stages. The power cylinder of 220 millimetres diameter and stroke has a piston and rod like that of an ordinary horizontal steam-engine, but the compressor of 150 millimetres diameter has a thick rod which fills the whole cylinder on the forward side but works like a plunger through a gland on the other side, leaving a narrow annular space between it and the cylinder, so that the air taken in is compressed from five to twelve atmospheres in the larger, and from twelve to eighteen atmospheres in the smaller space on the return stroke.

An ordinary plain slide-valve is used in the motor, the steam being regulated by throttling the exhaust. With 75 per cent. admission and making 120 to 130 revolutions per minute, it indicates 7·2 HP., while that of the compressor is 4·4 HP. or 61 per cent. useful work. The air cylinder is cooled by an external circulation of water, 2 litres per minute being required. Two cylindrical iron reservoirs are provided, one of 1·66 and the other of 1·77 cubic metre capacity. The second one was supplied in February, 1894, after an attempt to form a reservoir in the rock by rendering a portion of the level air-tight with cement had failed.

The locomotive consists of an iron air-vessel 3·160 metres long and 700 millimetres diameter, or 1·2 cubic metre capacity, mounted on two four-wheeled bogies 2·3 metres apart, running on the railway on the level which is of 410 millimetres gauge. The driving engines have two vertical cylinders 80 millimetres diameter and 200 millimetres stroke, and slide-valves governed by link motions. Both axles of the front bogie are driven, the forward one directly by the engines and the other one by spur gearing. When making 100 revolutions per minute with air at four to five atmospheres pressure, and cutting off at half stroke, the consumption is 0·200 cubic metre.

When moving at 90 metres speed per minute the useful effect is $1\frac{3}{4}$ HP. and the tractive force 34·6 kilograms. The air-supply for the engine is not taken from the large vessel but passes through an intermediate one with a reducing valve, where it is brought down to five or six atmospheres pressure, the latter being the extreme amount required in the steepest places on the road. The train-load consists of four mine-wagons, weighing 5 cwt. empty and 14 cwt. loaded; about ten minutes are required for each trip of 1,000 metres. On the arrival of the engine with a full train at the shaft, from five to six minutes are required for unloading the full- and arranging the return-train, during which time the air-vessel is filled at twelve atmospheres pressure for the return journey, an operation requiring about one minute.

During the ten minutes required for the return journey, the storage-reservoirs are filled up to eighteen atmospheres for bringing back the loaded train. This supply is carried by a 25-millimetre pipe 968 metres long to the end station, where the engine is refilled to fourteen atmospheres pressure while the later train is being made up, about three minutes being required for the filling. The average travelling speed is 1·6 metre per second, which is quite satisfactory as the road is very crooked, being partly carried along the lode and partly in cross-cuts, and includes several sharp-angled turns.

From fourteen to fifteen, with a maximum of eighteen, trips are made in a shift of ten hours (nine hours' working time). The net load is 36 cwt. per trip. The work is done by four hands: an engine-driver, a compressor-man who also does the unloading, and two fillers at the end station. Formerly six hand-putters were employed working two shifts to do the same amount of work.

The monthly working cost of the locomotive is given as £24 10*s.*, of which £9 15*s.* is charged to coal for the compressor for a net load of 740 tons hauled 1,000 metres. This works out to a slightly lower price than hand-labour, but with the further advantage that more work is done in the same time. The gross saving is £57 8*s.* per annum, which is reduced by allowing 14 per cent. for interest and depreciation to £11 11*s.*

The total cost of the different parts of the plant is given in detail in the final pages. These may be summarised as follows:—

	£.	s.	d.
Surface-compressor and boring-plant (1,014 metres pipes)	626	8	0
Winding-engine	91	11	0
Rock-breaking plant (344 metres pipes)	168	6	0
Locomotive hauling-plant (968 metres pipes)	327	12	0
Total . . .	1,213	17	0

The Paper is illustrated with several full-sized working drawings and plans.

H. B.

The Pyrites Mines of Sain-Bel. By — Drillon.

(Comptes Rendus de la Société de l'Industrie Minerale, 1894, p 193.)

The pyrites mines of Sain-Bel near Lyons are worked by the Saint Gobain Chemical Company, in a series of veins and lenticular deposits following the stratification of the old schistose rocks of the district for about a mile in the general direction N. 16° E. In the northern half of the area the veins varying from 1 metre to 8 metres in thickness, carry a little copper, and were worked from the middle of the last century until lately; but in the southern region the deposits are very much thicker, ranging from 4 metres to as much as 20 metres or even 40 metres of very pure iron

pyrites, containing 50 to 52 per cent. of sulphur and 45 per cent. of iron. These masses are heavily decomposed near the surface, the gozzans, which extend to the bottom of the present valleys, varying from 4 metres to 40 metres in depth.

At the present time the workings are concentrated in the principal southern mass, which is 600 metres in length, and is opened out by an adit level about 2,500 metres long, which cuts the Saint Gobain drawing-shaft at a depth of 118 metres. The mineral is removed in horizontal layers or stages 5 metres high, each of which is taken away in two lifts of 2½ metres commencing with the lower one. The first operation consists in driving a principal longitudinal gallery which may be either in the deposit or on one side of it according to the thickness. From this stalls are turned either way at right angles at intervals of 20 metres, the space occupied by the pillars being filled as they are removed with rock quarried at the surface. The working places are so arranged that the removal of the bottom lift and the laying out of the upper one may be carried on simultaneously, and similarly, during the removal of the latter, the main road of the stage next below is being driven. This method of working, which has been in use for twelve years, has been adopted as the most advantageous one of many that have been tried. Formerly the stages were driven at 30 metres apart, which allowed the first two lifts of 2½ metres to be removed easily, but the third was only got with difficulty, while the working of a fourth was found to be impossible. Another plan, based on the division of the deposit into pillars 12 metres square and the same height, was also unsatisfactory. At the present time the second lift of the thirteeenth stage is in process of removal, and the fourteenth is in preparation. The length of the mass at this level is 613 metres, the filling material, supplied by a surface quarry at either end, being sent down by self-acting inclined planes. The roadways bringing the mineral from the working-faces are laid on an incline of 1 in 140 towards the centre of the main level, whence the loaded tubs are carried by an endless chain to the winding-shaft, which is 4½ metres in diameter and 106 metres deep, to the filling place. The winding is done by a double-cylinder horizontal engine, of 700 millimetres (27½ inches) diameter and 1,800 millimetres stroke, with single deck-cages carrying four tubs with 11 cwt. each. The winding ropes are of Manilla hemp and the cage runs in wooden guides. The larger lumps of ore separated by screening are first broken down by a Blake rock-breaker, and subsequently reduced to the proper size for the pyrites burner by a Vapart crusher, the fine dust produced in the crushing being stored in a special hopper. There are four similar sets of crushing-plant, each including rock-breaker and Vapart mill, and capable of treating from 16 to 20 tons per hour, three of them being generally in use at the same time. From 16 to 18 HP. is required by each set. This is supplied by a Corliss engine of 440 millimetres (17⅓ inches) diameter, and 1,200 millimetres stroke, which also furnishes power for the underground

haulage in the main road of the thirteenth stage by means of a hemp rope carried down the Saint Gobain shaft at the back of the guides.

The mineral, after leaving the crusher, is sent by an automatic chain-traction down an inclined plane 1,632 metres long with an average inclination of 6·2 per cent. to the railway at Sain-Bel, where it is loaded into the main line wagons. The chain, made of round iron 26 millimetres (1 inch) in diameter, weighs 13½ kilograms per metre. The tubs follow each other at intervals of 22 metres, their proper distance apart being ensured by a signal bell, which warns the loader when it is necessary to start the next tub. The chain used underground weighs 12 kilograms per metre, and the tubs placed 20 metres apart travel at the rate of 1·7 metre per second (this, with 11 cwt. net load per tub, corresponds to a delivery of about 110 tons per hour). The output of the mine for the year 1894 will probably amount to about 270,000 tons.

The water issuing from the adit, about 300 cubic metres in twenty-four hours, being strongly charged with metallic sulphates, is neutralized with milk of lime before it is allowed to flow into the river. The precipitated material, collected in tanks of 50 cubic metres capacity, is subsequently utilized as gypsum, "ferruginous plaster," for agricultural purposes, or for gas-purifying under the name of "Sain-Bel Earth."

H. B.

The Limitation of the Gold Stamp-Mill. By T. A. RICKARD.

(Transactions of the American Institute of Mining Engineers, vol. xxiii., 1893, p. 137.)

In this Paper several interesting Tables are given of the wear of the shoes, dies, and screens, of the consumption of quicksilver, and the cost of milling at a number of representative mines, working under very dissimilar conditions, in the United States and Australasia.

The average wear of shoes and dies is given as 1¼ lb. of iron per ton of ore crushed, the wear being far greater in mills where no rock-breakers or automatic feeders are used. In properly equipped mills the wear does not exceed 7½ ozs.

The form of battery screen employed in various districts differs very considerably, and it is impossible to give the life of these, even for mills in the same neighbourhood, owing to various causes, *e.g.*, acidity of the water, size of hole, height of discharge, &c.

The Author does not consider there is any advantage to be obtained by employing double-discharge mortar boxes, as these take more water and have a less effective discharge, or splash, than the single-discharge ones.

R. E. C.

The Allotropism of Gold. By H. Louis.

(Advance Proof, Transactions of the American Institute of Mining Engineers, 1894.)

The Author commences by remarking that in the present state of knowledge, two well-defined allotropic modifications of gold can undoubtedly be recognised, namely, the ordinary yellow variety, and the red, brown, or purple non-lustrous amorphous variety, and goes on to give various chemical and physical data, from which he draws the following deductions:—

(1) Gold is capable of existing in allotropic modifications.

(2) One of these modifications is capable of amalgamation only with great difficulty, if at all.

(3) This modification is capable of being produced and of subsisting under conditions that may reasonably be supposed to exist in nature when gold is deposited in reefs.

The difficulty found in the Witwatersrand deposits of the Transvaal of catching the gold by amalgamation, he thinks, is very probably due to the gold having been deposited under such conditions as to render it allotropically indifferent to mercury. In conclusion he strongly recommends all scientific gold-miners to study more carefully the cause of the loss of gold in the process of extraction.

R. E. C.

Gold-Milling at the North Star Mine, Grass Valley, Nevada County, Cal. By E. R. Abadie.

(Advance Proof, Transactions of the American Institute of Mining Engineers, 1894.)

The operations at the North Star mine, which had been worked continuously for over twenty years, had in 1886 reached such a stage that it became imperative to erect a crushing-plant at the mine. Late in February 1887, thirty head of stamps and a building capable of containing a further ten head were completed, and crushing commenced the following month as soon as the water-power installation for driving it and the plant at the mine was finished. The mill site was a most favourable one, and the ore had only to be conveyed a distance of 142 feet from the top of the shaft to the bins above the stamps in the mill building. The mine trucks have a capacity of a little over 13 cubic feet, three containing about 2 tons of ore. These trucks are run to the mill and the ore tipped out over bar-screens or "grizzlies," fixed across the top of the ore bins at an angle of 40°. Each grizzly is 4 feet wide and composed of iron bars 3 inches × $\frac{3}{4}$ inch, placed on edge 2 inches apart. There are eight bins for the forty stamps, or one bin for each five head. The coarse ore passing over the grizzles is collected in coarse ore bins from which it passes to three (9 inches × 15 inches) "Blake" stone-breakers. These only require to be

run intermittently, aggregating not over seven hours out of the twenty-four. The crushed ore from the breaker falls into the fine ore bins along with the ore which passed through the grizzlies.

The eight fine-ore bins discharge their contents by gravity to automatic feeders, which keep the stamps regularly fed with ore. The free milling character of the ore only requires the simplest methods of amalgamation and concentration for the recovery of the gold it contains.

The arrangement of the mill is clearly shown in plan and elevation, and in several photographic views; drawings are also given of the battery frame mortar box and copper tables. The Paper concludes with two other complete Tables showing the total cost of working extended over several years, and the cost per ton of ore crushed.

The stamps when new weigh 875 lbs. each, and drop 7 inches eighty-six times a minute. The average life of the shoes, which are of steel, is 130 days, during which period they will crush 260 tons of ore, a new shoe weighing 159 lbs. being reduced to 38 lbs. The dies are of cast iron, and rest on a false bottom composed of two cast-iron plates 2 inches thick. The height of discharge varies from 4 to 6 inches. Brass wire No. 30 screens are almost exclusively used, although an experiment has been made with No. 0 tin screens. Amalgamation takes place inside the mortar-box as well as on plates outside. Two-thirds of all the gold recovered by amalgamation is found in the mortar-boxes. The Author refers to a method of recovering the amalgam from the plates introduced by himself, which he found gave excellent results. It consisted simply in pouring boiling water on the plates, or immersing them in it. The ore contains about 4 per cent. of "sulphurets," and concentration is performed on "Triumph" and "Frue" vanners, the concentrates being sold to local chlorination works. The gross production of gold for the year 1893 was £71,150.

R. E. C.

Preliminary Experiments on the Strength of Copper.

By Prof. A. Martens.

(Mittheilungen aus den k. technischen Versuchsanstalten zu Berlin, 1894, p. 37.)

In April, 1889, the German Minister for Trade and Commerce expressed the intention of instituting a thorough investigation on the strength of copper. It was intended to carry out these experiments in the course of the year, but this was found impossible unless the ordinary current work of the Institution was set aside.

The Central Committee of the German Union of Steam-Boiler Attendants declare "that the figures given in technical literature differ greatly, and it is very desirable that experiments be instituted

on the testing of copper." The communications from the divisional unions on the same subject are also given in the paper.

Scheme of the Experiments. (a) *General Arrangement.*—In order to make the investigation as wide and complete as possible, it was deemed advisable to make some preliminary experiments before entering on the principal series. These preliminary experiments were intended to throw light on the following subjects:—

(1) The influence the method of experimenting has on the result, and in particular: (*a*) the form of the test-specimens; (*b*) the method of preparing test-specimens; (*c*) the speed of testing; (*d*) increasing the load by definite steps, or continuously.

(2) The influence the condition of the material has, and in particular: (*a*) is it possible to produce a normal condition of the material by annealing? (*b*) what is the effect of repeated annealings?

Tension, bending and impact tests were made. The forms of the tension specimens were:—(*a*) 1·2 inch × 0·4 inch section, length between gauge points 8 inches; (*b*) 0·84 inch × 0·28 inch × 5·6 inches; (*c*) 0·28 inch × 0·28 inch × 5·6 inches; (*d*) 1·4 inch × 0·28 inch × 5·6 inches; (*e*) 2·8 inches × 0·28 inch × 5·6 inches.

The bending-tests were made on plates having ratios of breadth to thickness, 1, 3, and 5. They were bent (round a corner of radius equal to the thickness) right and left until fracture occurred.

The impact tests were made on cubes, or cylinders of height equal to the diameter, under a falling weight.

(b) *The Material and its Preparation.*—From the firm of C. Heckmann of Duisburg-Hochfeld, three plates, 32 inches × 34 inches × 0·48 inch, and six plates 32 inches × 26 inches × 0·36 inch, were obtained. The manner in which the plates were divided and numbered is detailed.

(c) *The Experiments.*—The following series were arranged:—(i) To decide whether the carrying out of fine measurements is desirable. (ii) To decide what influence the speed of test has on the results. These experiments were made on test-specimen (*b*), and the load was applied so that extensions of 0·2, 1, 2, 5, 7, 10, and 20 per cent. per minute were obtained. (iii) To determine the influence of temperature on heating, and the effect of repeated heating. (iv) To determine the influence of the treatment to which the specimen has been subjected. The effect of hammering, annealing, sudden cooling, punching, and drilling was determined by preparation of suitable specimens. (v) To determine the influence of the form of test-specimen on the apparent strength, and in particular to see if the new normal form of test-specimen (*b*) would give the same results as the usual normal form (*a*).

Results of Experiments: (A) *Results of Series III.*—The experiments were not actually carried out in the order laid down in the general plan. In order to carry out this series, temperatures up to 800° C. had to be obtained. This was easily done by the application of a bath of lead. As, however, there seemed a probability

of chemical action going on between the lead and copper, the following experiment was made :—Pieces of copper were placed in a shallow bath of lead and left several hours in the annealing oven at a red heat. They were then removed, the fluid lead wiped off, the ends which had been immersed were found to be perceptibly thinner than the ends projecting out of the lead. Thus a bath of lead is not applicable for long-continued heating.

Heating tests were made with hard-drawn copper wire 0·28 inch diameter, the test-specimens being 12 inches long. In series *a* and *a*′ the specimens were heated each two minutes to different temperatures, suddenly cooled in water and then tested, in order to determine at what temperature the softening of hard-drawn copper wire begins. In series *a*″ the specimens were heated to 300° C. for ½, 1, 2, 4, and 10 minutes, then cooled in water, in order to determine whether the duration of heating had any influence on the softening. In series *a*‴ the specimens were heated thirty-two times to 300° C., and to 350° C. two, four, and eight times, each time for half a minute and then cooled in water, in order to determine whether repeated change of condition had any influence on the softening. In series *a*⁗ the specimens were covered with different coatings to test whether the attack of the molten metal at a temperature of 525° C. could be avoided or lessened.

(1) *Influence of a Single Heating followed by Cooling.*—From the series of stress-strain diagrams for different degrees of temperature it is readily seen that a heating up to 300° C. produces an appreciable change, while at 400° C. the softening is almost completed. Also from a consideration of these curves it is seen that for hard-drawn copper there is no simple proportionality between the stress and the strain. With hard-drawn copper, again, permanent set occurs with very low stresses. A perceptible alteration in hard-drawn copper wire is produced by a two minutes' heating to 250° C., softening is produced between 300° and 400°, and heating to a higher temperature produces no perceptibly greater effect. Between 300° and 400° temperature of heating, both the maximum stress and the yield stress of the material sink considerably, while the ductility increases considerably.

(2) *Influence of Duration of Heating.*—From the stress-strain curves at 300° C. of specimens heated for different periods, it is seen that at this temperature the duration of the heating is of perceptible influence, while at a temperature of 350° it is quite pronounced. The breaking- and yield-stresses sink with increased duration of heating.

(3) From the experiments on repeated heatings and coolings, it is seen that by repeated heatings to 350° C. hard-drawn copper can be completely softened. The temperature to which hard-drawn copper can be heated without danger of a gradual change of strength is probably as low as 200° C.

(4) From the experiments with different coatings it seems that they have no influence on the result, but that copper may be

heated in a bath of metal for a short period without danger of chemical action.

(B) *Results of Series I.*—The differences of extension produced by the first loading are greater than on repetition of the same loads. There is no proportionality between stress and strain, not even on repeating the stresses inside the limits of the first applied stress. A plate of hard copper is, under a repetition of the load, stiffer than under the first load, for stresses over 3·5 tons per square inch.

The "after" extension in the first and second minutes after the application of the load begins with a soft plate at zero stress, and with a hammered plate at a stress of 5–7 tons per square inch. Permanent set occurs both with soft and hard copper at the lowest stresses, though it is naturally much greater in soft copper than in hard. By a repetition of the load the yield-point is raised above its original position.

(C) *Results of Series II.*—It is found that the velocity of extension of the test-specimens, between the limits 0·2 per cent. and 22 per cent. per minute, has no perceptible influence on the breaking-stress; that it has a perceptible, but (in comparison with other influences) practically negligible, influence on the yield-point, which increases with increased velocity; and has a very small influence on the extension and contraction of area. These results are of great value for practical testing, as the capacity of the testing-machine may be increased by shortening the time taken to carry out a test, without at the same time influencing the results.

(D) *Influence of Form of Test-Piece on the Results.*—If the test-piece is not of unusual shape, especially if its length is not too short, the stress at the yield-point and the maximum and breaking-stresses are practically independent of the form of the section.

The influence of the method of measurement on the value of the extension is discussed. In particular it is pointed out if the fracture occurs near the end of the length over which the extension is measured, the extension being greatest in the neighbourhood of the fracture, the value of the extension of the material will be less than if the fracture occurs at the middle. The Author recommends that for the determination of the extension, all bars in which the fracture occurs outside the middle third of the measured length be rejected.

The influence of the form and size of the transverse section of the test-piece is discussed, and it is declared that the transverse section has practically no influence on the extension, provided the measured length be taken proportional to the square root of the sectional area.

The law of similarity, or of proportional resistance, may be expressed thus:—Geometrically similar bodies of the same material experience geometrically similar changes of form under the same stresses.

The experiments of Barba on different forms of test-piece are discussed.

(E) *Results of Series V.*—With soft plates of copper, the form of

the test-piece within the limits of series v has no perceptible influence on the increment of extension for a given increment of stress, nor on the value of the "after" extension in the first and second minutes under equal loads.

With soft plates the form of the stress strain curve from the larger test-specimen 1·2 inch × 0·4 inch is perceptibly different from that of the smaller test-piece 0·84 inch × 0·28 inch. This experience contradicts the law of similarity. With hard-hammered plates both sizes of test-pieces give the same form of stress-strain curve.

The Author recommends that in the principal series of experiments to follow, so far as possible a single form of test-piece (*b*, 0·84 inch × 0·28 inch) be used, and in cases where this is not possible proportional forms be used. If proportional forms be impracticable, the ratio of measured length to the square root of the sectional area should be constant, and equal to 11·3. The divisions along the test-piece should be $0 \cdot 565\sqrt{f}$ (f being the sectional area), and the extension measured over five or ten divisions from the fracture.

(F) *Results of Series IV.*—The test-pieces were hammered, from strips 0·36 inch thick, down to 0·22 inch, 0·26 inch, and 0·30 inch. Hammering raises the yield-point to more than four times its value in the normal state of the metal, but raises the breaking stress only slightly. The extension is greatly diminished, and the contraction of area slightly diminished. Hammering therefore raises the limit of stress and lessens the ductility. A plate of hard hammered copper on being annealed is brought back almost completely to its original state; the effect of cold working can therefore be neutralized by heating. A plate which is first worked and then heated is considerably softer than one which is first annealed and then worked. A plate cooled in water is somewhat harder than one slowly cooled. These results are expressed in the values of the maximum stress, and stress at the yield-point.

The cold-punching of a plate of copper raises the yield-point and lowers the breaking-point; by rimering out the hole the injurious effect is only in a small degree removed. In drilled plates, on the other hand, the yield-point and breaking-point are greater than in a solid plate. Drilling appears therefore not to have the same bad effect as punching.

(G) *Results from Test-Pieces repeatedly Broken.*—A certain amount of work having been done on a bar subjected to tensile stress, if subjected to a second test in the same direction the material will show a smaller capacity for work. In order to throw light on this question, from each end of a broken test-piece (*e*) two small test-pieces were prepared. On applying the second test three years after the first, the ratio of the increments of strain and stress are considerably lowered for all stresses. In this case also there is no proportionality between the stress and strain. The greatest alteration is shown by the material in its normal state and when annealed; while the hammered plate on the second test shows practically the

same result as on the original test. If after the first test the plate is heated for six minutes to 500° C. the stress-strain curve from the second test is practically the same as from the first.

The yield-point is raised to 3·7 times, the breaking-point to 1·3 times; the extension is reduced to 0·02 time, and the contraction of area reduced to 0·8 time the original values. Also, the difference between hard hammered and soft copper quite vanishes on breaking the specimens a second time.

(H) *Tenacity of Copper at Different Temperatures, and the Influence of Different Mixtures.*—The experiments of Mr. Rudeloff[1] on the influence of heat on copper are referred to. On the influence of different mixtures, the experiments of Professor Roberts-Austen and of Professor Thurston are discussed. The Author remarks that these experiments give no information on the elastic properties and the yield-point of copper, and that altogether the series of experiments is too short.

(I) *Results of Impact-Tests.*—These tests were made by crushing cubes by repeated blows of a hammer. The influence of hammering is not clearly shown by these impact-tests. Experiments at different temperatures showed that under the same circumstances cubes of soft copper required considerably less specific work to produce a definite change of height than cubes made from hammered copper. The resistance to impact at high temperatures is considerably lower than at ordinary temperatures both with soft and hammered copper.

(K) *Results of Bending-Tests.*—By a misunderstanding the bending-tests were not carried out as intended. The tests by bending to and fro will be better made in the principal series of experiments.

(L) As a measure of the extent to which a specimen has been worked the Author recommends the use of the expression

$$\frac{\sigma_S}{\sigma_B} \text{ and } \frac{\sigma_B}{\sigma_S}\,\delta_n,$$

σ_S and σ_B being the yield-point and maximum stresses respectively, and δ_n the extension measured on an original length $n\sqrt{f}$, f being the sectional area of the specimen.

(M) *Working-Stresses for Copper.*—The Author says that the working-stresses that can be safely allowed to copper under various conditions can only be satisfactorily determined after a series of duration tests has been made.

(N) In conclusion it is seen that:—The form of the test-piece has considerable influence on the result, especially on the extension. Similar forms should be used in order to reduce this influence to the smallest possible amount.

The method of preparing the specimens affects the result. It is recommended that only cutting tools be used for the purpose.

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[1] Minutes of Proceedings Inst. C.E., vol. cxvii. p. 461.

The influence of manner of applying the load (continuously or by finite amounts) may be practically neglected.

It is possible to produce a normal state of the material by annealing, in which a temperature of at least 500° C. must be reached.

The Paper is accompanied by thirty-six Tables and seventy-six figures of illustration.

A. S.

Report of the Commission on the Testing of Old Boiler-Plates.

By — Otto.

(Mittheilungen aus der Praxis des Dampfkessel und Dampfmaschinen-Betriebes, 1894, p. 379.)

This report was communicated to the Prussian Boiler-Protection Union at their meeting at Eisenach. The commission have been investigating whether it is necessary to apply a chemical test in order to specify exactly the quality of a plate. Three plates of wrought-iron of about 22·9 tons per square inch tenacity, and one wrought-iron plate of 26 tons tenacity, were analysed as to the quantity of carbon, silicon, manganese, phosphorus, sulphur, and copper. Test-pieces from each plate were subjected to different treatments, and then tested as to tenacity and extension. From the results of the experiments, which are not by any means exhaustive, the Commission think it incorrect to specify in general a maximum or minimum percentage of single elements. They also are not prepared to recommend a chemical analysis, but rather higher values of the figures for bending and extension. The injury to wrought-iron plates by working at a blue heat is brought out by the experiments; and the Author remarks that so far back as 1881 at the meeting at Halle he called attention to the fact that not only mild steel, but wrought-iron plates were injured to a certain degree by working at a blue heat.

The results of experiments of the Commission on old plates are represented by a coloured lithograph, in which the percentages of carbon, silicon, manganese, phosphorus, sulphur, and copper, the tenacity and extension of the plates, when new, and after being subjected to ordinary working stresses for years, are represented. From a comparison of the original values with those determined after dismantling of the plate, it is seen that both the tenacity and the extension diminish with working; the latter to a greater degree than the former.

A. S.

Improvements in Wire-Rolling.

(Stahl und Eisen, October, 1894, p. 845.)

A new method of casting small ingots of homogeneous iron and rolling the same direct into wire has for some time been successfully practised at the Hasper Iron and Steel Works. The basic-steel department, of which a ground-plan accompanies this notice, contains three 5-ton bloom converters together with three cupola-furnaces for melting pig-iron. The basic lining-material of the converters is prepared in an adjoining building, which contains a furnace for burning dolomite, an edge-runner crushing-mill, a Belgian mill, a mixer, hydraulic brick-moulding machines, a drying stove and a hydraulic crane. A blowing-engine of new design furnishes the blast for the converters, a second being kept in reserve. The cupola-furnaces are served by Root blowers, which are also provided in duplicate. The casting-ladle is mounted on a steam-wagon running directly over the casting-pit, which is of great length and is served with four differential and two auxiliary cranes. The pit is constructed wholly of iron, and is of sufficient size to contain three ingot-casting arrangements and two groups of ordinary chill-moulds. The entire contents of a 5-ton converter can be received by a single set of moulds, the product being forty ingots, each weighing 264 lbs., or forty-eight weighing 220 lbs., or sixty weighing 176 lbs., as may be desired. The moulds are closed at the top by easily removable plugs of conical shape provided with air-holes, which, in the event of ingots remaining stuck fast in the moulds, facilitate their ejection. The casting of small ingots in this way has proved to be very satisfactory, the metal being in perfect condition for drawing into rods. There is a hydraulically-worked shearing-apparatus by means of which the feeding-heads of the ingots are shorn off at the moment at which the steel begins to solidify. The use of this contrivance dispenses with the services of eight workmen who were formerly required, and tends to increase the durability of the moulds. When the operation of casting is completed, the whole group of moulds is raised to the level of the foundry floor by means of a hydraulic ram placed under the casting-plate. The average production of the steel-works per shift of twelve hours is twenty-nine charges, each yielding 4·7 tons of good ingots.

The duplex ingot-rolling mill adjoining the steel-works is served by two rotary furnaces, the waste heat of which is utilized by placing a cylindrical tubular boiler over them. The ingots are delivered at the mill by means of an air-way, and, after being weighed, are placed in the furnaces by a hydraulic elevator. The wire-rolling mill consists of a set of rolls, 15·6 inches (400 millimetres) in diameter, driven direct by an engine making 90 revolutions per minute, a second set of the same size, driven by a belt, being kept in reserve alongside it. A pair of shears for

cutting the rods is provided with each set of rolls, which latter are made of forged steel. Ingots 150 millimetres (5·85 inches) in section and weighing 120 kilograms (264 lbs.) are drawn out into bars 1·87 inch in section in nine passages.

When coils of rods weighing from 110 to 121 lbs. (50 to 55 kilograms) are rolled, each rod is cut into two equal parts, of which one is conveyed to the roughing-rolls on the right hand and the other to similar rolls on the left. When coils weighing from 33 to 38 kilograms (72·6 to 83·6 lbs.) are rolled, the rods are cut into three parts, two of which go to the rolls on the right and the third to the left in the first instance, and one to the right and two to the left in the next, and so on alternately. When coils weighing from 25 to 28 kilograms (55 to 61·6 lbs.) are rolled, the rods are cut into four parts, of which two go to the right and two to the left for further treatment.

At the wire-drawing mill, which is situated at some distance from the steel-works and consists of an ingot-roll, a roughing-roll and a finishing-frame, ingots weighing from 80 to 85 kilograms (176 to 187 lbs.) are rolled, this being the limit of weight for ingots to be drawn out direct into wire one after another at a finishing roll.

The average output of the rolling-mill per shift of twelve hours is 56 tons of wire of 4·9 millimetres (0·19 inch) diameter, or as much as 64 tons of thicker wire.

A. H. C.

Armour Plates and their Production.

By Prof. F. Kupelweiser.

(Stahl und Eisen, June 1894, p. 552.)

This Paper was read before the Austrian Society of Engineers and Architects on the 24th of February, the subject being treated under the following heads:—

1. Welded iron plates.
2. Compound plates.
3. Homogeneous steel plates.
4. Harvey plates.
5. Nickel steel plates.
6. Effect of projectiles.

The Paper includes a description of the production of nickel steel plates at Witkowitz. The construction of the plant for the manufacture of armour-plates was begun in the year 1889, at which date the new steelworks and the 2,000-ton press were already erected. The earlier ingot rolling-mills were rebuilt in the year 1890, so that armour-plates might be rolled. The open-hearth arrangement of the new cast-steel works consists of four furnaces having a capacity of 12 tons, the beds being formed of

the basic material, magnesite. Each furnace is served by a shaft gas-producer of 5 feet internal diameter in which coal is distilled, a blast giving a water-gauge of 7·8 inches being employed.

The casting arrangements consist of a travelling ladle-crane that runs on a line of railway parallel with the row of furnaces. When very heavy ingots are required for the production of armour-plates, the molten metal from several furnaces is collected in a single ladle which is moved by a 70-ton travelling crane, and has at the bottom a plugged hole through which the metal may be tapped. The Author describes the construction of the casting-pits, which are rectangular in section and rest on a cast-iron bottom, in the centre of which is a mould, formed in sand, for the production of the trunnion by means of which the casting is manipulated at the forge.

The alloying of the molten metal with nickel is effected either in the open-hearth itself, or, in smaller pieces, in the casting-ladle. The pit is warmed before casting is commenced, and the metal is poured slowly into it so as to prevent as far as possible the formation of deep cavities due to the great amount of contraction which the nickel suffers. When the ingots have become cooled to such a point that they can be lifted out of the pit, they are delivered to reheating furnaces, two of which are gas reverberatory furnaces of large size with producers similar to those of the open-hearth, and the third a grate-fired reverberatory. The hearths of these furnaces are 23 feet in length by 16·5 feet in width, and their working doors are raised and lowered by hydraulic power. In one of these furnaces the ingot is heated to such a degree that it may be forged to about half its thickness by means of a 2,000-ton hydraulic press, built by Messrs. Tannett, Walker and Company, of Leeds. The Author describes this forging-press in detail, and mentions others of greater power used elsewhere.

Ingots of 30·31 inches maximum and 28·34 average thickness are forged in three or four heats to about 15·74 inches. The forging-trunnion is then removed, and the ingots thus prepared are delivered to the rolling-mill, where, in one heat, they are reduced to the desired thickness, usually 7·8, 10·6, or 12 inches.

The reheating furnace for the plate rolling-mill has a rotary hearth after the Pietzka patent, and, in its normal position, lies parallel with and opposite to the rolls, at a distance of about 130 feet. Behind the furnaces there is a hydraulic apparatus for drawing the ingots into and out of them; and between the rolls there are four small hydraulic lever arrangements by means of which the ingots are guided straight if going obliquely to the mill or are turned over if necessary.

The dimensions of such rolling-mills do not differ considerably at the various forges, the length and diameter being, respectively, at Witkowitz, 137·8 and 37·4 inches; at Dillingen, 141·7 and 39·3 inches; and, at Essen, 157·5 and 49·2 inches.

Engines of more than 1,000 HP. are required for the driving of

these mills. The rolled plates are, after thorough cooling, cut with a cold saw, and dressed by large planing and shaping machines. For the production of 100 kilograms (220 lbs.) of finished plates, 208 kilograms (457·6 lbs.) of ingot steel are required, or a charge of 227 kilograms (499·4 lbs.) in the open-hearth furnace.

A. H. C.

The Earth as an Electrical Conductor. By J. H. Holt.

(The Electrical World, New York, 1894, pp. 290 and 310. 1 Fig.)

The Author states that the fact that the earth could be used to conduct electric currents, was discovered by Steeiheil at Munich in 1837, while experimenting upon the Nüremburg-Fürthet Railway to ascertain whether or not the track could be used as one of the conductors of a telegraph-circuit. He noticed that the current would pass from one rail to the opposite one traversing the earth, and this led him to believe that he had discovered a most excellent conductor having practically no resistance. Since that time it has commonly been believed that a body having such an immense cross-section should offer little or no resistance to the current. About two years ago, at the Alabama Polytechnic Institute, it was desired to transmit power from an Edison dynamo on the College Campus to a motor some 3,000 feet distant for the purpose of working a cotton-gin, threshing machine and other plant. It was decided to use the earth as a return in the belief that thereby the cost of copper conductor would be reduced by half. The result was, however, that sufficient power could not be obtained at the motor to work even the lightest machinery successfully, proving that there must be an immense drop on the line, and showing that the plan of using an earth return was impracticable.

A test was made by the professor who had charge of the work by means of a Wheatstone bridge, and the resistance was found to be very high, and the Author was desired to carry out a complete set of tests.

Ground connections were made, one near the power-house on the College Campus called station A, and another at the farm called station B. Connection at each was made with earth by using large earth-plates, one of copper, and the other of tin. Each plate measured 7 feet by 2 feet, and had soldered to it a No. 0000 bare copper wire, and was placed in a pit 8 feet long, 2 feet broad, and 6 feet deep, and around the plates charcoal and iron filings were well packed, and pieces of scrap iron thrown in before the pit was filled up with earth. Besides the earth-plates, a thin sheet iron plate 2·5 feet by 3·5 feet was placed in each of two wells 20 feet away from the earth-plates, and these were also used. The well-plates and ground-plates were connected by short copper wires, with a switch so that the well-plates or ground-plates could be used alone or both in parallel or series.

The line between the terminal stations was divided into six parts, each 500 feet long. At each intermediate station ground connection was made by driving down flush with the surface of the earth a wrought-iron rod 6 feet long and 2½ inches square, to each of which was soldered a copper wire which could be easily connected to the overhead wire. The geological formation was investigated by the aid of four wells, and by digging at each station to a sufficient depth. The top station was found to be a drift deposit which covered all the hill-tops; in this drift were found water-worn pebbles. Underlying this is one of the older formations, probably Laurentian. The portion surrounding the terminal station consisted of a very red clay soil containing a great deal of iron.

The Author then gives further details of the geological formation, and proceeds to describe the experiments made to determine the resistance between the terminal earth-plates. The first series was made with current from a dynamo, using a Weston voltmeter and Thomson graded amperemeter. The results obtained were as follows:—

Volts.	Amperes.	Calculated Resistance.
		Ohms.
60	0·54	111
70	..	112
90	..	113
110	1·15	112
150	1·36	115

Readings were obtained at intervals of 10 volts from 60 volts, and the average of all the ten gave 111·1 ohms as the earth-resistance.

The earth-plates were then disconnected and the well-plates switched in. The same method of testing was again used, and with 60 volts and 0·4 ampere the resistance was 150 ohms and increased to 187·7 ohms at 150 volts and 0·8 ampere, the average of the readings being 174·9 ohms. This showed that the resistance was much higher when well-plates were used than when earth-plates were employed. Well-plates and earth-plates were then connected in parallel, and at 60 volts and 0·65 ampere a resistance of 92 ohms was obtained, which increased at 70 volts to 93 ohms, and then, as the pressure rose, fell to 80 and 79 ohms. It is, therefore, advantageous to connect well-plates and earth-plates in parallel. The line was now short-circuited for a few days to get rid of the effects of the dynamo current and then allowed to remain open for a day.

Another series of tests was next made, using three Daniel cells and a Wheatstone bridge, with a very delicate reflecting galvanometer. With earth-plates as grounds the resistance varied from 65 to 106 ohms. This method is obviously very unreliable. The earth-

plates were switched out and the well-plates connected when the resistance varied from 78 to 131 ohms. With earth-plates and well-plates in parallel the resistance appeared to be from 63 to 70 ohms. The same battery current and apparatus were of course used in all the preceding tests.

The next set of tests was made from station to station along the line, using a few secondary cells and the same Wheatstone bridge and galvanometer as before. From the first earth-plate to station 1 at a distance of 500 feet, the resistances calculated were 183·3, 185·5, 212·2, and 221 ohms respectively. The resistance of the first 500 feet is thus seen to be greater than that of the whole 3,000 feet. The connection of station 1 to the overhead wire was then broken and station 2 connected instead. The calculated resistance between the terminal earth-plate and station 2, a distance of 1,000 feet, was 333·3, 355, 382·2, and 390 ohms. Station 2 disconnected and 3 connected gave between the terminal earth and station 3, a distance of 1,500 feet, a resistance of only 63, 79·5, and 85·9 ohms; this station is in a valley and about 30 feet from a small stream.

From the terminal to station 4 the resistance was 514·2, 555, 561, and 583 ohms, an average of 555·3 ohms. Finally, to station 5 the resistance was 217, 237, 328 and 353 ohms, an average of 225·8 ohms.

The Author states that the variation in the calculated results is not due to inaccuracy of the instruments, but to polarization of the earth-plates.

The resistance was then tested by using alternating currents, and a method used in getting the specific conductivity of electrolytes was employed. The results obtained were as follows:—

	Ohms.
Resistance of earth between terminal earth-plates . . .	92·4
" " " " wall-plates . . .	121·0
" " " well-plates and ground-plates in parallel	66·8
" " " terminal and station 1 . .	201·6
" " " " " 2 . .	374·7
" " " " " 3 . .	92·0
" " " " " 4 . .	506·3
" " " " " 5 . .	180·0

The Author concludes that the resistance of the earth return is much higher than is usually supposed. The matter of making ground connections is one that depends upon local effects, and the best results are not to be obtained by placing the ground terminals in water, or by simply placing them in any soil that seems to be a damp one; but plates or rods should be placed in good conducting strata, and it must not be assumed that the earth is anything like a perfect conductor.

E. R. D.

Direct-Current Machines for the Three-Wire System.

By — von Dolivo-Dobrowolsky.

(Elektrotechnische Zeitschrift, 1894, p. 323. 4 Figs.)

The Author remarks that owing to the saving in conducting material effected where the three-wire system is used for direct currents, this system is now very generally employed. The chief disadvantage in its use is that two machines must always be at work together, and although this arrangement may be of but slight importance to a large station, it is disadvantageous in small stations.

There have been many attempts to work upon a different system from that of Dr. Hopkinson, and specially with the view to using one machine which could be assisted by other single machines as the load increased.

The plan first proposed by Siemens to use a third brush upon the commutator is not feasible in practice, as this would short-circuit the coils in the strongest part of the field, and would so produce great sparking.

Another method is also due to Messrs. Siemens and Halske, and this is the use of a single dynamo and two equalising motors in series with one another and mechanically connected together. Any arrangement of this kind must be capable of dealing with variations of 10 per cent. of the maximum output, so that with dynamos of 1,000 HP. the equalisers must be able to develop 100 HP. Besides the space and other requisites, this system lowers the efficiency of the installation, as current is necessarily wasted in the equalisers. Equalisation by accumulators can only be profitably used where accumulators are put in for other purposes.

The Author then proceeds to describe a newly-patented system of his own which is being used by the Allgemeine Elektricitäts Gesellschaft, who have licensed the Compagnie de Fives-Lille to manufacture in France. The principle of the design is shown diagrammatically in the original, a Gramme ring two-pole machine being illustrated. Inside the ring, and connected to two points diametrically opposite, is placed a coil of great self-induction but low resistance, and it is intended to revolve with the armature. The Author then proceeds to show that not only is the potential difference the same between the ends of the central coil and its middle, but that also the potential difference between each commutator brush and the centre of the coil is the same. It is therefore obvious that the centre point of the coil can be used as a point of connection for the third wire in the three-wire system.

In practice it is not considered advisable to allow the coil to rotate with the armature, as that method would be inconvenient, but the coil is preferably wound upon a closed ring core, and the ends of the coil are connected to a pair of brushes which press upon

a small contact ring beside the commutator. The Author remarks that the application of the principle to machines with more than two-poles is of course easy, and it is clear that dynamos so provided can act as motors, and can therefore be used for equalising purposes. In the case of a three-wire system feeding a distant distributing point the third wire can be done away with, and some of these new machines used in its place; then, in case of unequal loading of the two sides of the system, one half of the machine would act as a dynamo and the other half as a motor.

This equaliser only divides the potential equally, when the want of symmetry of loading is not too great when compared to the output of the dynamo. If, for example, the potential loss in the armature at full load were about 4 per cent., then with a difference of loading of 10 per cent. the deviation from the half potential would only be 0·4 per cent., and is unimportant even supposing the resistance of the potential divider itself added an error of 0·5 per cent. It is therefore obvious that the potential is divided with sufficient accuracy. With the three-wire system the loss of potential in the third wire is often so great that in spite of careful division of pressure at the station, the two groups of lamps burn with unequal brightness. This can be allowed for on the Hopkinson system by raising the potential of one of the dynamos, although it cannot be done on the potential-divider system, but regulating resistance coils can be put into the leads which will absorb about 4 to 5 volts. A better method is to insert a variable electromotive force in the third wire. For this purpose a small dynamo can be put in the third-wire circuit, and driven either by a motor or by belting. This neutral machine affects both sides of the system but in opposite ways, and therefore if there is an inequality of 10 volts a 5-volt dynamo will serve. If equality within 2 per cent. will serve, the machine might be for 4 volts only, the wires need only be large enough for the third-wire current, that is, for about 10 per cent. of the current in the outer leads, therefore the neutral machine would only be of $\frac{1}{4}$ to $\frac{1}{3}$ HP. for a generating dynamo of 100 HP. The Author states that the neutral machine would be best wound as a series dynamo. Although the system described either with or without the neutral machine is applicable to both large and small stations, the Author considers it specially adapted for the latter. He remarks then in small stations the extra cost of the two-wire system is often preferred to the complication necessary in the switching arrangements for the Hopkinson system.

E. R. D.

Alternating Currents and Fuses.

By Prof. DUGALD C. JACKSON and R. J. OCHSNER.

(Transactions of the American Institute of Electrical Engineers, 1894, p. 457.)

Experiments made at Cornell University indicated a rise in resistance and lowering in fusing-point of fuses traversed by alternating currents, and the experiments described in this Paper were carried out to ascertain whether the results were correct.

The samples tried comprised fuse-wire intended for 5 amperes, obtained from five different manufacturers, some 30 ampere fuse-wire and wires of copper, German silver and iron. Pieces of each kind of wire, 9 or 10 feet long, were wound on pine rods 1½ inch diameter and 1 foot long, substantial terminals dipping into mercury cups being provided.

The resistance was measured by an "Anthony" bridge to four places of decimals and all results reduced to 20° C., the mean temperature of the room. The coefficients for this purpose were determined by allowing the room to cool to the outside temperature on one day and by heating it on the next, a range of temperature of about 16° C. being thus obtained. A table of the coefficients is given.

The fuses were connected in series with one another and with a resistance on a 110-volt circuit, having a frequency of 125, the current being 3 amperes, and were run continuously except for about nine hours on Sundays. The resistance was measured at intervals and the results plotted, the curves for the several wires being given. It was found that the heat due to holding a fuse firmly in the hand was sufficient to raise the resistance 1 per cent., and the results were affected by the heating effect of the bridge battery, though the error was made negligible by making contact for brief periods only. The wires took a long time to cool down, the alternating current was accordingly stopped for a time and the resistance measured from day to day; it was then put on for about 100 hours and the resistance measured daily, the wires being taken into a cool room for a time and then allowed to stand in the testing-room for five or six hours before being measured. The Authors conclude that there is no appreciable rise of resistance, at any rate within a period of 550 hours.

It was next sought to ascertain whether the fusing-point had been affected by the passage of the alternating current. The 5-ampere fuses only were tried; a gradually increasing current from a storage-battery being passed through pieces of wire 6 inches long, soldered to heavy copper terminals dipping into mercury-cups. Ample time was given for the current to heat the wire as the fusing-point was neared.

A number of pieces of each kind of wire were taken, half of new wire and half of wire through which the alternating current had passed during the experiments described. Four kinds showed a

slight lowering and two a slight rise of fusing-point; although very small, the Authors think there was a slight change and they ascribe it to oxidation of the wire.

The Authors arrive at the conclusion that the fusing-point is not affected by the fusing-current, and that the experiments made at Cornell University are unreliable.

C. H. W.

The Potential- and Current-Curves of Different Types of Alternators. By G. Roessler and W. Wedding.

(Elektrotechnische Zeitschrift, 1894, p. 315 *et seq.* 15 Figs.)

This Paper treats of the potential- and current-curves of alternators and of their influence upon the candle-power of alternating current arc-lamps.

The Authors remark that recently attention has been re-directed to the fact that although arc-lamps may have been most carefully regulated at the works where they were made, they still require a very different regulation for steady burning when placed in their working position, even though the potential and current are the same as those used for the tests. This result is due to the difference between the curves for potential and current of the test supply and that actually in use.

If these curves differ widely, as when a different type of alternator is in use from that employed for testing purposes, cases arise in which it is impossible to regulate the lamp properly. It is therefore desirable to secure, if possible, uniformity in the number of alternations per second used for arc-lamps.

For the choice of the frequency two questions must be answered: (1) how does the lamp burn? (2) what candle-power does it give with different types of potential- and current-curves? These questions can only be answered after experiments have been made, and after electrical and photometric measurements have been taken simultaneously. The Authors carried out these experiments in the electrical laboratory of the Technical High School in Berlin, at Easter, 1894. The electrical results are due to Mr. G. Roessler, and the photometric part to Mr. W. Wedding.

Three alternators were used, a 5·5-kilowatt machine by Ganz & Co., with four poles and a star-shaped armature; an older small 480-watt machine by Wechsler & Co., with four poles on each side of the rotating armature; both these belonged to the laboratory; and besides these two a third machine, built by Messrs. Siemens and Halske for their own use; this had twelve poles, and was intended for the preparation of ozone, but was placed at the service of the Authors. The alternating arc-lamp used was made by Messrs. Körting and Mathiesen of Leipzig. The determination of the periodic curves for potential and current which the machine delivered to the lamp was effected by the

now classic method used by Joubert in 1881. One terminal of a voltmeter is permanently connected to one of the terminals of the arc-lamp, while the other two terminals of the arc-lamp and voltmeter are momentarily put into circuit with one another, once per revolution of the shaft, at a certain position of the armature in the magnetic field.

With a suitable graduation of the voltmeter the potential difference for each position of the armature can be measured; similarly the current can be known by determination of the potential difference at the ends of a non-inductive resistance of known value. The Author then describes the exact arrangement of the contact pieces by means of a diagram. A Carpentier electrometer in connection with the rotating contact-maker served for the measurement of the potential and current, and was of great use owing to its aperiodic action. In order to diminish oscillation as much as possible, a Siemens mica condenser of 1 microfarad capacity was connected in parallel with the electrometer, and this condenser acted as a damper. With the double connection used the angle of displacement is proportional to the square of the potential difference, so that it is not sensitive enough for low potentials.

About 20 volts was the lowest potential difference exactly obtainable, and for lower values the quadrant connection method was used, and the displacement is proportional to the potential difference. The Author points out methods of avoiding errors, and proceeds to describe the precise method adopted in the experiments. Besides the electrometer the following apparatus was used: a Cardew voltmeter in parallel with the arc-lamp under test; a Thomson electro-dynamometric balance for a range of 0·1 up to 10 amperes; a Schuckert amperemeter for alternating currents, and a wattmeter by Ganz & Co. By means of a non-inductive resistance the measurements of potential were taken with the electrometer and these served to plot the current curves. The Thomson balance was only used for the first regulation of the lamp, after which the Schuckert instrument was employed. As owing to the regulating apparatus a perfectly constant position of the electrometer could not be obtained, ten readings were taken for each point upon the potential- and current-curves, and the mean of these used for plotting. During the photometric tests four pairs of curves were taken for the Ganz machine, and two pairs for each of the others. The results are given in the form of Tables and also plotted as curves.

The first Table deals with the potential, current, and energy results, for the Ganz machine; the readings were taken at intervals of 5° round the circumference of the insulated disk, and the alternations were 42 per second; similar Tables follow for the other machines. A comparison of the curves shows that that of the Ganz machine is unsatisfactory, and that all the energy is given to the lamp in a very short period.

The Author proceeds to discuss the relative advantages of the different types, and states that the Wechsler machine gives the

best curves, and that this result is greatly due to the wide air-spaces between the armatures and pole pieces. The Siemens machine differs from the Ganz machine chiefly in the large pole-pieces of the field-magnets and armatures, which are so wide that the corners of adjoining pieces are very near together.

The Author then makes a careful comparative analysis of the three machines, and draws attention to the small difference in phase between the potential- and current-curves; this only averaged one-eighteenth part of a half period. The construction of the arc-lamp is described in detail, and note taken of the changes in regulation necessary to cause it to work well with current from each alternator. The photometric part of the Paper due to Mr. Wedding follows. The lamp was intended for a current of 10 amperes, and carried above the arc one of the usual white-enamelled reflectors so that the light was thrown down.

The lamp with a little practice could be regulated so that the maximum fluctuations did not exceed 0·3 volt. The difference of potentials on the whole tests lay between 28·8 and 31·1 volts. The carbons used were made by Messrs. Siemens Bros. & Co., and known as A cored carbons, 10 millimetres diameter. The photometric arrangements were those in ordinary use at the Berlin electrical laboratory. Details are given of the types of instruments used, and of the method of calibration. The observations are tabulated and also drawn graphically. It appears that the average results were as follows: where E is the potential difference at the terminals of the lamp in volts, C the current used in amperes, and W the watts.

—	E	C	W
Ganz	29·7	9·4	262
Wechsler	31·1	9·3	286
Siemens and Halske .	31·0	9·1	269

The Wechsler machine, working at 40 alternations per second, gives a better result than that of Ganz & Co. The Siemens machine would not feed the lamp at this low frequency, and was worked at 60 and 80 alternations. At the higher speed it gave the best result of the three.

The Author finally concludes that direct-current arc-lamps are more efficient than those working with alternating currents.

E. R. D.

Three-Phased Power Transmission at Taftville, Conn., U.S.

(The Electrical World, New York, 1894, p. 619. 3 Figs.)

The first important application of electrical power transmission to textile manufacture has just been installed by the General Electric Company at Taftville, Conn., the power being transmitted from Baltic to Taftville, a distance of nearly 4·5 miles. The three-phase system is used, and motors of the synchronous type are employed, not only to work one of the largest cotton mills in the United States, but also the power-station of the Norwich, Conn., Street-railway.

In the basement of the Baltic mill upon the Shetuget River is placed the generating plant. The mill is of four storeys built of stone, and will be used like the Ponemah mills at Taftville in the cotton-weaving industry. Four hundred feet above the mill a fine stone dam 525 feet long has been built across the river. The effective head on the turbines is 32 feet, and the water available even in the driest seasons is sufficient to develop 1,500 HP.

The turbines drive the pulleys on the main shaft by means of belting. These pulleys are thrown into or out of action by Hunter clutches mounted with pulleys on sleeves, so that any or all of the wheels can be applied to driving the shafts. Similar apparatus is used in the dynamo room.

There are three double 42-inch horizontal turbines and one double 27-inch turbine; of the former each develops 800 B.HP. at 157 revolutions per minute, and the latter 300 HP. at 244 revolutions per minute. The speed of the turbines is kept constant by means of Schenck electric governors; the turbines and shafting were made and erected by the P. C. Home Company of Gardiner, Me. In the dynamo room are two 250-kilowatt three-phase generators, built by the General Electric Company, running at 600 revolutions per minute, and delivering current to the line at 2,500 volts. Each machine has its own exciter, a 3-kilowatt bipolar dynamo.

The generators can be run in parallel if desired, and for this purpose the switch-board is furnished with synchronizing apparatus, the acoustic synchronizer being placed on the face of the board and the equalizing switch at the back. No artificial load is required when putting the machines in parallel.

The conductors are carried upon stout wooden poles placed 100 feet apart. There are two cross arms, the three wires on the upper one being of No. 0 B. and S. gauge bare copper, and there form the original three-phase circuit, the four wires on the lower bar being No. 0000 insulated wire, one being used as a reserve.

At Taftville two three-phase self-starting synchronous motors, exactly the same as the generators, are installed, and replace two Corliss engines of 350 HP. previously used. The motors come up

to speed in about fifty seconds after starting, and each is supplied with an exciter. The efficiency of the plant at full load, from the power applied to the dynamo pulley and that delivered to the motor pulley, is just 80 per cent. There is work enough for both motors driving the 1,700 looms in the new mill, operating the lighting plant and the three 80-HP. railway generators built by the General Electric Company and placed in another part of the basement.

E. R. D.

Experiments upon Electrical Transmission of Power at Oerlikon.

By Dr. BEHN ESCHENBURG.

(Elektrotechnische Zeitschrift, 1894, p. 261 *et seq.*)

The Author states that some time ago experiments were made at the Maschinenfabrik Oerlikon, in Switzerland, upon a conductor used for ordinary work, with the view of obtaining data as to the results to be expected when high potentials were used. The theory of these actions has been known for several years, and the character of the experiments and of the results is essentially in agreement with the well-known trials of Ferranti at Deptford. The chief difference was that at Oerlikon an overhead line was used, and the potential was raised to 33,000 volts, and careful measurements of the watts were made. The arrangements for the experiments were as follows. The conductors for the transmission of power from Bulach to the Maschinenfabrik Oerlikon consist of four wires, each 0·158 inch diameter, and 14·26 miles long, mounted upon 230 wooden posts, with a total of 920 oil insulators, and at an average height of 39·37 feet above the ground. For two years these conductors have served daily for the transmission of energy from water-power at the Glatt von Bulach to the works at Oerlikon by means of a three-phase current of 15,000 volts potential between each pair of wires; three wires were thus in use, and the fourth was kept as a reserve in case of accident to one of the others. For the experiments the ends of each pair of wires at Bulach were joined together so that a lead and return wire 28·52 miles long was available from Oerlikon. In the works two transformers in oil baths were used, and each had a capacity of 40 kilowatts and a ratio of transformation of 1 to 15. A 50-HP. Oerlikon alternator supplied current at a potential of 2,000 volts to the primary winding of the first transformer. The current was then sent through the line wire to Bulach and back again, and then into a step-down transformer to bring the potential to 2,000 volts. The current then passed into four 10-kilowatt transformers coupled in parallel, and the potential was thus lowered to 200 volts, and the energy absorbed in non-inductive resistance coils. The measurements obtained were the number of alternations n of the generator per second; the exciting current J_0 of the generator, the difference of potential between

the terminals E_1, the primary current J_1, the output in watts W_1 of the generator, the amperes of current at each end of the line wire, and the current J_3 and potential E_3 of the tertiary current transformed down to 2,000 volts. The arrangement is shown diagrammatically in the original, from which it appears that the generator was connected to the primary of transformer No. 1, and a voltmeter was placed across the leads while an amperemeter and wattmeter were placed in the circuit. Similarly a voltmeter and an amperemeter were put in the tertiary circuit. The Author then goes into a discussion of the theory of the action of the apparatus, and gives a long series of differential equations. Afterwards, he quotes some of the actual results obtained. With the generator running on open circuit the following measurements were obtained :—

Alternations per Second.	Exciting Current.	Potential.
	Amperes.	Volts.
55	8	810
	10	1,008
	15	1,530
	20	1,810
	22·8	2,160

A similar series of results are tabulated for 63 alternations per second. When the machine was short-circuited, $n = 63$, $J_0 = 6 \cdot 6$ amperes, and the armature current was 16 amperes.

With the machine loaded direct—

	Amperes.	Volts.	Amperes.
$n = 63$	$J_0 = 12 \cdot 5$	$E_1 = 1{,}224$	armature current = 16
	$14 \cdot 0$	1,440	19

The exciting currents, 12·5 and 14 amperes, correspond according to the characteristic curve with electromotive forces E of 1,450 and 1,710 volts, so that the resistance of the line $R = 1{,}440 \div 19 = 76$ ohms.

When the transformers were directly coupled in series, the following results were obtained running idle :—

	Volts.	Amperes.	Watts.	Volts.
$n = 53 \sim$	$E_1 = 2{,}000$	$J_1 = 1 \cdot 9$	2,300	$E_3 = 2{,}000$
$62 \sim$	920	1·12	—	920
	1,320	1·35	—	—
	2,140	1·92	2,300	2,140

The resistance r_2 of the secondary coil of the first step-up transformer was found to be 188 megohms, and the resistance of the primary coil 0·84 megohm.

The energy lost in magnetization at a frequency 53 and 2,000 volts was 2,300 watts. The capacity of the line was obtained by formula as 0·25 microfarad.

It appeared that there was a total loss of 4,500 watts, of which 2,300 watts was as shown lost in the transformers, and 1,600 watts lost through the resistance of the first transformer, owing to the current being greatly in excess of the capacity of the transformer.

Only about 1,600 watts were lost in the line itself: this corresponds to a current of about 0·03 ampere, which, at 33,000 volts potential, leaked away down the total 920 insulators, giving an insulation resistance of 3 megohms. A similar result was obtained with the ohmmeter made by Messrs. Hartmann and Braun, using 20 volts, although an insulator may, to all appearance, be sound at a low potential, while faulty at such a high one as 30,000 volts.

The Author gives tabulated results obtained with the transformers in circuit with the line. He states that the loss of potential in transformers coupled in series, so far as the fall is occasioned by leakage, is four times as great as with a single transformer. The efficiency is 97 per cent. reckoned from the results obtained on open circuit and the resistance losses. The Author then makes a comparison between the results obtained from the formulas he has previously given and the actual experimental results obtained.

The electromotive force of the dynamo at 42 alternations per second is about one-third of the difference of potential between the terminals, and that at 63 alternations is only about 40 per cent. less than the terminal potential.

One of the results obtained is that the primary current when on closed circuit is less at times than on open circuit with a similar potential in the primary circuit. The observations gave for open circuit 1,300 volts and 42 amperes, and for closed circuit 31 amperes.

The Author claims to have shown that by fairly simple calculations all the essential results can be obtained qualitatively and approximately quantitively when the following data are known. (1) The coefficient of self-induction of the dynamo; (2) The current on open circuit of the transformer; (3) The coefficient of magnetic leakage in the transformers; and (4) The capacity of the line.

E. R. D.

The Electrical Power Transmission from Laucherthal to Sigmaringen.

(Elektrotechnische Zeitschrift, 1894, p. 354. 4 Figs.)

On the occasion of the construction of new rolling mills, the directorate of the mining company, of which the Count of Hohenzollern is at the head, gave to the Elektricitäts-Aktiengesellschaft, formerly Schuckert and Co., the concession for the construction and working during a period of forty years of an electrical installation. This installation consists of an electric-lighting plant for the town

of Sigmaringen, which also supplies the castle and the administration buildings. The whole plant may be divided under two headings: (1) an electrical power-transmission plant by means of high-potential direct current; (2) an electric-lighting plant with accumulators.

The lighting plant is carried out on the three-wire system, and the mains are partly above- and partly underground. The accumulator battery has a capacity of 750 ampere-hours, and the cells were built by Messrs. C. Pollak and Co., of the Frankfort accumulator works, and have given good results. The most interesting feature, however, is the employment of water-power in Laucherthal, 3·1 miles distant, for the supply of the necessary energy. The ironworks at Laucherthal possess on the Lauchert a waterfall with 31 feet head, and this actuates two turbines, each of 182 HP., built by J. M. Voith of Heidenheim. The relative positions of the machines is shown upon a cut in the original; one turbine is used to drive the dynamos while the second is used for the rolling-mills, but it can be used if required as a reserve, and take the place of the first.

The turbines chosen were of a special type, with horizontal suction-tube and shaft running at 115 revolutions per minute, and direct coupled to the transmission shaft.

As only two dynamos of about 90 HP. each will be at work at the same time, each turbine is built for a normal consumption of 53 cubic feet of water with a head of 31 feet, and then develops 144 HP. with an efficiency of 76 per cent.; the guide-vanes can, however, be opened so as to admit of a consumption of 70·63 cubic feet, and an output of 182 HP. An automatic governor controls the inlet to each turbine so that the output can be regulated within wide limits. The Author states that there is no fear of flooding, as the floor of the turbine-house is 9·8 feet above the tail-water and the turbine shaft about 13 feet above the same point.

The dynamo-pulley is made double the width of the driving-belt, and for each of the three dynamos a fast and a loose pulley is provided upon the main shaft. The loose pulley is first caused to press tightly against the fast pulley so as to start the dynamo, and after that the belt is slid on to the fast pulley, and the loose pulley again freed from contact.

In the generating-station, which is directly below the rolling-mills in Laucherthal, are installed three four-pole series-wound dynamos, and each develops at 460 revolutions per minute 1,100 volts and 61 amperes. In order to diminish the loss in transmission these machines are run two in series, so that a potential of 2,200 volts is obtained; the third machine acts as a reserve.

The transmission is on the three-wire system. The Author then refers to a diagram in the original and gives details of the switches. Special safety-apparatus was required by the German Government, which, in case of a break in the wire or a short circuit, at once cuts off the dynamos.

In the case of a short circuit of the transmission wires a magnetic apparatus cuts off the field magnet circuit at once.

At Sigmaringen three four-pole dynamotors are installed, each machine consisting of a series-wound motor, driving direct a shunt-wound dynamo. These machines run at 410 revolutions per minute, and deliver into the town net-work, for lighting and power work, 46,000 watts, or more than 70 per cent. of the energy produced at Laucherthal.

The motor which receives the main current works with a current of 61 amperes, and a potential between the brushes of 940 volts, the rest being lost on the line, and develops about 70 HP.; this drives the dynamo direct, and the latter is used for the charging of accumulators, and develops 170 amperes at a pressure of 260 volts. If desired, the pressure can be raised to 370 volts with less current while working at the same speed. The three motors are used exactly in the same manner as the dynamos, two being employed in series, leaving the third as a reserve. The motors are practically similar to the dynamos used as generators, except that in the case of the motors the iron frame is of somewhat smaller cross section to give a greater magnetic resistance. The normal speed of the motors is 410 revolutions per minute, and at one-third load this only rises to 415, and with a still less load it falls again to 410 revolutions; constant speed of the generators is of course essential.

The generating- and receiving-stations are connected by an overhead line about 3·1 miles long, which is carried upon double bell insulators of porcelain fixed to wooden posts 39·5 feet high. The outer wires are of copper-wire, each with a cross section of 0·062 square inch, while the middle wire has a cross section of 0·031 square inch. The distance from post to post is about 49 yards.

Every fourth post is provided with a lightning guard, which is connected to a barbed wire carried by all the posts, and the latter wire is put in connection at frequent intervals with damp earth. Lightning guards are provided also at the generating and receiving stations; and iron netting is placed under the conductors wherever they cross railway or public roads.

The motors will start with a current of 20 amperes at 200 volts, and this energy is sensibly reduced in ordinary work.

Between the 1st of April and the 1st of October 1893, besides the installation of the complete generating and receiving stations at Laucherthal and Sigmaringen respectively and the overhead line, 3,000 incandescent lamps, 20 arc-lamps, and several motors were put down, and the Author states that the whole plant has given great satisfaction.

E. R. D.

The Grassot Meter for Continuous Currents. By A. Perrin.

(Annales Télégraphiques, vol. xxi., 1894, p. 243.)

The instrument is an ampere-hour meter, and its action is electro-chemical; it is therefore adapted only to continuous-current circuits of constant potential.

A pure silver wire, accurately drawn, is placed in a vertical position, its upper end being furnished with a weight sliding in a glass tube, which serves as a guide, while its lower end, conical in form, rests on a glass stop placed a short distance below the surface of a bath of silver nitrate, the end being thus immersed in the liquid. The bath contains also a silver plate serving as a kathode.

The voltameter thus formed is connected in series with an extra resistance of such a value that the resistance of the bath may be neglected in comparison with it, and the whole is placed as a shunt across the ends of a German-silver coil of low resistance through which the current to be measured passes. The current is led into the silver wire by a fork-shaped spring which presses it against a drum having a roughened surface and carrying a pointer on its axle; the axle drives a second, also carrying a pointer, which serves to show fractions of a revolution of the first.

As the current passes, the end of the wire wears away, allowing the wire to descend, and thus cause the drum to turn, the amount of its motion being proportional to the quantity of silver dissolved and therefore to the whole quantity of electricity which has passed. The point of the wire wears conical, but if it becomes blunted from a jar or other cause the registration is not affected, provided it is not necessary to take a reading at the time, since the wire remains stationary until the conical form is again attained. Similarly, if the wear of the point is irregular or it becomes distorted so that it moves in jerks, the total amount registered during a long period is not affected.

The instrument is mounted in a wooden box with glass windows allowing the dial and terminals to be seen, and so made that the meter can be readily changed when the wire or bath requires renewal.

The advantages claimed are:—(i.) absence of magnets and mechanism introducing friction uncertain in amount, also freedom from temperature error; (ii.) registration with very small currents; (iii.) absence of waste on open circuit, further economy resulting from the possibility of recovering the silver; (iv.) silence in working; (v.) low price.

C. H. W.

Alternating-Current Measuring-Instruments. By W. Peukert.

(Elektrotechnische Zeitschrift, 1894, p. 462.)

The Author describes in this Paper a somewhat novel form of electrical-measuring instrument suitable for use as amperemeter or voltmeter with alternating currents. The principle on which it is based is essentially that first shown by Professor Elihu Thomson, according to which a copper ring is attracted to or repelled from a coil surrounding part of an iron core also passing through the ring. This device has been elaborated by von Lang and the Author into instruments of a commercially working form; the original apparatus first used consisted simply of a straight iron core (composed of fine wire) about 9 inches long by 1½ inch diameter, mounted vertically on a wooden base, which also carried a wooden frame to support the coil at a point nearly half-way up the core. The coil consisted of six layers of fourteen turns each, in a double winding of fine copper wire; current from an alternating generator with a frequency of 45 to 50 per second was passed through the coil, and an aluminium ring (about 2 inches diameter and 1½ inch high, weighing 7 grams) was slipped over the core so as to rest upon the coil. In proportion to the current flowing through the coil, this ring was repulsed upwards and kept balanced in the air at a varying height. By attaching a light frame pivoted overhead, with a counterweight to balance the action of gravity upon frame and ring, a pointer or index-finger, also attached to the frame near the pivot, was made to show on a scale the relative movement of the ring up and down under the influence of a varying current.

In the instrument of commercial form arranged according to this principle, the moving ring is of copper, thereby increasing the inductive effect; and it is carefully balanced by an adjustable counterweight to mark zero when no current passes. Obviously the appliance may be used either as a voltmeter or an amperemeter. According to curves, drawn by the Author, of measurements taken on this appliance, an almost unvarying ratio is shown between increase of current or electromotive force, and the graduations on the scale throughout its entire length; this result, the Author thinks, follows largely from the fact that no moving masses of iron are employed; even iron cores are not absolutely necessary, so that the effect of remanent magnetism or hysteresis is largely if not altogether avoided. The curves both for rising and falling currents give similar results. When employed in alternate-current work, these instruments are not of course quite independent of the periodicity, but the variations—as evinced by curves accompanying the article—do not appear to be very great or important, tests being made with currents at frequencies between 73 and 104 per second. The effect of difference in current frequency may, moreover, be readily nullified by

any of several well-known methods. Instruments measuring current up to 10 amperes and electromotive force to 50 volts have shown excellent results in comparison with a Siemens electro-dynamometer and a Cardew voltmeter.

Several illustrations and graphic diagrams showing curves accompany the article.

F. B. L.

The Olan Electric-Current Recorder.

(The Electrical Engineer, New York, vol. xviii., 1894, p. 162.)

The instrument is intended to record simultaneously the current and the pressure in a circuit. Two coils are provided, one of low resistance, the other of high, each actuating a pointer; the deflection of the first pointer being proportional to the current, of the second to the pressure. The position of the pointers is recorded at intervals on a sheet which is kept moving before them by time mechanism; the records may be on the same or separate sheets. The impression is made by perforating the sheet, either by causing the pointers to vibrate by means of electro-magnets actuating armatures fixed on their ends, or by causing sparks to pass from their ends to the sheet.

C. H. W.

Telephone-Cables with Dry-Air Circulation. By A. Barbarat.

(Annales Télégraphiques, vol. xxi., 1894, p. 193.)

The telephone-cables exclusively employed for a long period in Paris were insulated with gutta-percha and lead-covered; a detailed specification of them is given by the Author. Though their flexibility renders them easy to lay, and a bad section can be replaced without difficulty, there are serious objections to them, viz., large capacity and high resistance, want of durability (lasting eight or ten years at most), joints take a long time to make, and, finally, the cables are dear.

For long-distance work, Fortin-Hermann cables which have a low capacity have been used. The latest cable of this type consists of fourteen conductors twisted together in pairs, each conductor being formed of seven strands of copper 0·0197 inch diameter, insulated by means of beads of paraffined wood threaded on them. These beads are cylindrical and are 0·31 inch long and 0·16 inch external diameter. The seven pairs twisted together are covered with a casing of lead 0·118 inch thick, the diameter over all being 1·14 inch; the length of a coil is 219 yards. The specified resistance per mile of each conductor is 20·9 ohms at 24° C.; the insulation resistance per mile 621 megohms, and the capacity per

mile 0·97 microfarad. The figures attained are usually 19·7 ohms and 0·072 microfarads per mile. The insulation varies with the dryness of the air in the cable, but 621 megohms per mile can easily be exceeded.

Joints are made by means of an ebonite sleeve having fourteen grooves on its circumference in which the conductors are laid; these having been jointed, another ebonite cylinder in halves is placed over them, and over this is drawn a lead sleeve to which the ends of the coverings of the cables are soldered.

The cables terminate in wooden end-pieces formed of two hollow parts; on the under side of one of these is fixed an ebonite base to which binding-screws are attached: these pass through the wood to the outside.

These cables are fairly easy to lay, but care has to be taken not to break the wooden beads. Their chief advantage lies in their low capacity; the insulation is well maintained so long as the lead is not pierced; once this happens it rapidly falls, and there existed no means of raising it until the method of employing dry air described in the Paper was devised.

The Author was first led in 1891 to try the effect of drawing dried air into a faulty cable to raise its insulation, and the result was so successful that it is now regularly employed for repairing cables. Instead of drawing air in by means of an aspirator, it was found preferable to blow air into the cables, compressed air from the pneumatic tube service being employed for the purpose, there being danger with the former method of moist air entering at unknown points; moreover, if there are punctures in the lead, the compressed air can be heard escaping from them, thus revealing their presence. In order to allow the air to circulate, holes about $\frac{1}{3}$ inch in diameter are bored through the ebonite cylinders.

In the original desiccator, calcium chloride and sulphuric acid were employed, quicklime being used to prevent any trace of acid being carried into the cable, but the acid has now been abandoned on account of the danger of the vessel containing it bursting under pressure. The Author gives full details of a very large desiccator used in conjunction with compressed air derived from the Popp system of distribution in Paris, the higher pressure being necessitated by the method being applied not only to the Fortin cables but also to those insulated with paper or cotton. The air is supplied at a pressure of 71 lbs. per square inch, and, as this is higher than is required, a regulator, of which details are given, is used for varying it between 14 lbs. per square inch and 42 lbs. per square inch. The dryness of the air is tested from time to time by passing some of it through a known weight of sulphuric acid.

This device of blowing in dry air is now employed when laying new cables, and much simplifies matters, since the elaborate precautions formerly taken to prevent the access of moist air during jointing are no longer necessary, the cables being dried after laying.

The wooden terminal pieces not being sufficiently air-tight, the

ends of the cables are blocked up with paraffin, and a tube is soldered to the lead casing to provide for the admission of the air.

In the Paterson cables, the insulating material, cotton or paper, was formerly saturated with paraffin; but by the use of dry air circulation, this can be dispensed with except for a length of 10 or 11 yards at the ends, the capacity being rendered much lower thereby. Jointing has been also much facilitated by doing away with the use of paraffin. The construction of the latest form of these cables is fully described, and details given of their dimensions and electrical properties, also of the terminal boxes and the method of jointing.

Tests have shown that dry-air circulation can be applied to Fowler-Waring and Felton-Guilleaume cables, and indeed to all those insulated with paper or cotton without paraffin or other insulating material, provided the ends are blocked up and the method of jointing modified as described.

The advantages accruing from dispensing with paraffin are enumerated; not only is it unnecessary to take precautions to avoid the entrance of moisture—a matter of extreme difficulty when working in culverts—but much time is saved by not having to separately test each wire in the joint for insulation, it being only necessary to make sure there is no dead contact with the lead. The greatest advantage, however, consists in the facility for repairs, for, whereas when a puncture occurred in paraffined cables there was no alternative but to cut out a faulty section and go through the tedious process of remaking the joints, the cable being useless meanwhile, with dry-air circulation it is merely necessary to find the aperture and solder a piece of lead over it, no interruption in the service taking place, since conversation is quite possible over a cable with poor insulation. If, instead of a simple perforation of lead, the covering of the wires themselves is damaged, it is only necessary to strip back a portion of the lead and insulate the wires with cotton or silk tape; a split lead sleeve is then slipped over them and soldered up. In this way, even with so serious a fault, no interruption of the service takes place. This method of repair has only been actually tried with the Fortin cables.

The Author is of opinion that the drying-stove might be dispensed with during the manufacture of cables of this class, and this has been done in the case of Fortin cables. The dried air under pressure is led into the cable at the moment it leaves the lead press; the drum on which it is wound has a hollow axle, one end of which is connected to the cable by a rubber tube, the other turns in a sleeve through which the air enters. The flow is kept up until the cable is cold in order to avoid ordinary air being drawn in by the contraction of that in the cable. An insulation of 6,200 megohms per mile is easily attained.

The Author's experiments lead him to believe that for underground work cables adapted to air circulation are far preferable to those which he calls "full," *i.e.*, which are covered with gutta-

percha or other solid material. He prefers paper made from some substance having a long fibre to any other form of cellulose. He goes into the question of the manufacture of the cables, and discusses the various items of cost, showing clearly the small saving effected by diminishing the thickness of the lead, which he recommends should always be made substantial.

The cables can be easily laid in a trench, in which case the Author recommends that they should be protected from acids in the soil by means of melted pitch, their not being affected by heat admitting of this; as a mechanical protection, steel ribbon or wire or hollow bricks may be used.

The Author next describes a portable air-compressing and drying apparatus, and refers to the application of the cables to telegraphy and electric lighting.

The Paper concludes with a description of experiments made to ascertain the effect of the passage of air for different periods of time, and a detailed account is given of the successful repair of a cable, the insulation of which had been purposely reduced to 5 ohms by the introduction of water.

C. H. W.

The Manhattan Incandescent Arc-Lamp.

(The Electrical Engineer, New York, vol. xviii., 1894, p. 160.)

In this lamp the arc is surrounded by a small globe through which the carbons freely pass; this globe is contained within a larger one, which is air-tight, except at the bottom where a hand-hole is provided to admit of cleaning and trimming the lamp; the hole is closed by a yielding metallic disk.

When the lamp starts, the air within the globes is heated and partially expelled; the remaining oxygen is converted into carbon-monoxide, which gas, together with the nitrogen, surrounds the carbons in a highly rarefied condition. By this means the combustion of the carbons is much retarded, ½-inch carbons (no length is specified) being said to burn for eighty hours without retrimming, the globe not being blackened or discoloured. It is claimed as an advantage that the difference of potential across the carbons is considerably increased.

The mechanism of the lamp is all fixed concentrically with the central stem. A switch is arranged on the base of those for outdoor use in such a manner that the lamp can be removed without affecting the main circuit, while the indoor lamps have an enamelled iron rheostat arranged as a "head-board" with terminals, metal straps for suspending the lamp, and a switch, porcelain insulators being used to separate it from the ceiling.

C. H. W.

The Johnson-Lundell Electric Railway System.

(The Electrical World, New York, 1894, p. 651. 4 Figs.)

A new system of electric-railway traction has been under experiment upon a track on private grounds in the upper part of New York City. The system is the joint invention of Messrs. E. H. Johnson and Robert Lundell. The track runs round a whole city block and has somewhat steep gradients and curves of short radius.

The generating-plant consists of a vertical engine driving directly a pair of Lundell dynamos, the unit being chosen as of suitable size for a commercial undertaking.

By means of an interior conduit telescopic iron tube, current is carried to the track at the proper feeding points, and no leakage is said to occur, as the ducts are well insulated.

The track consists of ordinary rails, and between them it is asphalted or paved, and parallel with the rails lies a conducting bar embedded in the asphalt. The bar is level with the surface and divided into sections by blocks of stone. Outside the single track, or midway between the double track, are plain watertight boxes with iron covers, flush with the surface of the street, and these boxes contain electro-magnetic apparatus which delivers current to the particular section of the track as the car comes along, and then falls until the next car comes along. The car carries a rubbing brush, and the road is not alive except underneath the car; besides this the two sides of the circuit have practically no difference of potential between them, so that there is no danger to horses. Each car has only one motor, and this is placed centrally under the body, and drives on to each axle by means of bevel gear, and with sprocket wheels and link chain in flexible connection. The suspension is flexible, the gear wheels are boxed in, and by means of a double spiral spring in connection with the armature shaft the motor can be started and stopped without jerks.

Under the seats are placed lead storage-batteries, sufficient to supply 300 volts, which is the working pressure; these cells will carry the car over crossing places, and also serve to light the interior. The Author states that the chief advantage of the Lundell type of motor is, that it can be instantaneously reversed without danger. The batteries are charged upon the road while the cars are at work. The track appears to have been subjected to very wet weather last winter, but this did not prevent efficient working. It is claimed that the special winding of the motor gives it all the flexibility of two motors. The Author has been very favourably impressed with the results obtained with this system.

E. R. D.

Electrical Tramway at Lyons. By A. Moutier.

(L'Electricien, 1894, p. 169.)

The Author describes a new system of electric traction devised by Messrs. Claret and Wuillemier for a tram line 2 miles long, laid to convey passengers to the recent Exhibition at Lyons.

Working on the same lines as Messrs. Ayrton and Perry and Mr. Leireff, these engineers have succeeded in maintaining an efficient service throughout the summer. Exposed contact-rails 9 feet long are laid at intervals of 10 feet up the centre of the track. These are insulated by wood and bitumen from the ground and from each other, and are only connected to the main cables when the car is passing over them. This automatic connection with the generating station is effected by distributors placed in pits or kiosques at intervals of about 110 yards. The separate contact-rails, which are of iron, are joined up by means of insulated cables to successive radial contacts arranged sunflower fashion in the distributor.

An insulated disk driven by clock-work carries brushes which rest on the radial contacts and connect these one by one to the main conductor as the car passes on to their respective rails. This motion is regulated by an electro-magnetic escapement.

Each car has two collecting-brushes, one at either end. Immediately the front collector moves on to a fresh contact-rail, which is at that instant idle, a current is returned through it to an electro-magnet in the distributor, and hence to earth. The armature of this electro-magnet releases the clock-work and allows the brush to move on by one step and connect the rail to the main cable. The rail which the car is leaving is at the same time disconnected.

The Author describes fully the construction of these distributors where required for either single- or double-track working, in order that they may maintain an efficient "block system." For use on single tracks the driving gear and electro-magnetic escapement becomes more complicated as the direction of rotation of the brushes is not constant.

The necessary pressure between the collectors on the car and the iron contact-rails is obtained by permanent magnets. The magnetic attraction between the rubbing pole shoes and the rails is opposed by springs which raise the contact immediately the collector passes from the rail. The main cable, which is lead-covered and iron-armoured, is laid on one side of the track, and connected to each of the distributors. The insulated wires from the distributors to the individual rails are protected by wood under the track. The rails are used as the return wire.

The generating plant consists of a 100-HP. gas-engine, using a poor gas manufactured on the Buire Lancauchez system, a six-pole Thury dynamo, and the necessary switch-boards.

A four-minute service was maintained throughout the day by means of twelve cars. Each car, when loaded with forty-two

passengers, weighs 8 tons 14 cwt., and is driven by means of a double reduction gear by a 20-HP. motor. The ratio of reduction is 12 to 1, and a speed of about 18 miles per hour is obtained. The voltage used is 500, and the Author states that no accidents have occurred owing to faults in the distributing system.

During the month of August, 123,842 passengers were carried on this line, but the Author gives neither the working expenses nor the first cost. The article is fully illustrated.

R. W. W.

The Zurich-Hirslanden Electric Street Railway.

(Elektrotechnische Zeitschrift, 1894, p. 356. 3 Figs.)

The Author states that the electric street-car railway from Zurich to Hirslanden differs from all other street railways from the fact that in the generating station itself secondary batteries are used to equalise the load upon the machines. It was at first intended to use machines only, but the responsible contractors for the work, who were the Maschinenfabrik Oerlikon, after being approached by the Hagen accumulator works, made satisfactory preliminary tests and eventually decided to use secondary batteries. It appears from a diagram in the original that the generating machine is shunt-wound, and the battery is in parallel with it across the mains; so that thus a constant load is obtained upon the engine which works at its highest efficiency. There are special automatic cell-regulator switches which are controlled by the potential, and the dynamo, therefore, charges a varying number of cells. The cells which lie between the charge and discharge points are charged by a small auxiliary shunt machine; and the field magnet coils of the latter being across the leads to this varying number of cells, automatic control of the dynamo is obtained.

Automatic magnetic cut-outs are used in the circuits to prevent the current from the cells driving the dynamo as motors.

The conductor is carried on poles and is divided into four parts insulated from one another. The track is metre gauge 2·8 miles long, and there is only 233 yards of level line. There are 3,300 yards of gradient varying from 0·15 to 3 per cent., 880 yards varying from 3 to 5 per cent., and 543 yards varying from 5 and above per cent. The steepest grade is 6·48 per cent., which is in the Klosbachstrasse and is 87 yards long, while it has a curve of 27·2 yards radius at the end.

From the power station up to the Kreuzplatz, a distance of 4,950 yards, the sum total of all the rises gives 124 feet, which is an average rise of 0·837. In the contrary direction the total of all the rises is 210 feet, which gives an average rise of 1·41 per cent.; the average rise, therefore, in each direction, is 1·127. Each

carriage is built for twelve persons sitting, and twelve to fourteen persons standing. The weights are as follows—

	lbs.
Car empty.	5,050
Weight of electrical apparatus	3,200
Weight of passengers, driver, and conductor .	3,960
Total	12,210

The greatest output of energy is required in the Klosbachstrasse, where as stated the gradient is 6·48 per cent. With a coefficient of traction of 26·4 lbs. per ton, and a speed of 10·8 feet per second, the work required is 18·8 HP. at the motor. In order to be able to start, 25 HP. must be available. If it be allowed that the average load of the car is only 1,320 lbs., which is a low estimate, then the average total weight moved is 9,570 lbs.

The single journey lasts twenty-six minutes, and with two minutes' stop at the end the double journey occupied fifty-four minutes. So that the Author estimates that the average output of the motor is 4·72 HP., allowing for 25 per cent. excess at starting. The power station is at the end of the line, and provided with two Galloway boilers, built by Messrs. Escher Wyss & Co., of Zurich. Each boiler has a heating surface of 624 square feet. One boiler acts as a reserve. There are two large steam-engines, each of 90 HP., but capable of developing 100 HP., and one small engine of 5 HP. Each of the two large engines drives by belting a shunt-wound dynamo, which develops from 450 to 550 volts and 100 amperes. Only one set is at work at one time, so that there is one always in reserve. The small engine drives direct a shunt-wound dynamo, developing 100 volts and 30 amperes, or 150 volts and 20 amperes; this is the auxiliary machine previously alluded to, and it has been found that it need only be worked once in two or three days for some hours. The station is so arranged that as much more power could be put in, giving three times the output, with a complete set in reserve.

The batteries are placed between the boiler-house and the engine-house, and consist of 300 cells, with a capacity of 245 ampere-hours; the charging current is 63 amperes, and the normal discharge 81 amperes, but this rises to 162 amperes, and on emergency 243 amperes can be taken out. The charge is sufficient to carry on the whole work of the line for three hours.

The special automatic double-switch is designed for 150 amperes, and to control twenty-eight groups of three cells each; it moves over two contacts per second, and, therefore, can switch in or out eighty-four cells in fourteen seconds.

There is a six-minute interval car service, and also a twelve-minute interval service; with the former nine cars are on the road together and with the latter five cars.

If the efficiency of the dynamo, allowing for loss in the belt, be taken at 90 per cent., an average loss in the conductors of 5 per

cent., an efficiency of the motor and apparatus at 80 per cent., and loss in the accumulator of 5 per cent., then the total combined efficiency will be 64·98 per cent. Taking the average output per car at 4·72 HP., then the steam-engine must develop about 65 HP. for the six-minute service, and about 36 HP. for the twelve-minute service. The current at 520 volts will be 83 amperes for the six-minute service, and the result is that about 80 amperes are constantly given out by the dynamo, while there is a varying effect on the battery from 30 amperes charge to 30 amperes discharge, the line current required varying between 50 and 110 amperes.

From 6.16 A.M. to 7.04 A.M. there is a twelve-minute service, from 7.04 A.M. to 7.58 P.M. a six-minute service, and from 7.58 P.M. to 9.04 P.M. a twelve-minute service. This gives a six-minute service for twelve hours fifty-four minutes, and a twelve-minute service for one hour fifty-four minutes. The total daily output is therefore 907 B.HP. hours, and as 2,960 lbs. of coal are consumed, there is a consumption of 3·3 lbs. of coal per B.HP. hour. In power-stations where no accumulators are used for street-car service, the Author states that 5·5 lbs. of coal and upwards per B.HP. hour are used, so that there is a daily saving of 2,000 lbs. of coal; and, with coal at 31*s.* per ton, this is a yearly saving of £516 due to the use of the battery.

The battery and switch apparatus complete, erected in working order, cost £1,480, so that yearly one-third of this is saved in coal; allowing 5 per cent. for sinking fund, and 5 per cent. for repairs, the battery would be paid for out of coal savings in four years. One of the chief advantages, however, is that it is unnecessary to keep the second boiler in steam. The Author also points out that the coal consumption will hereafter be diminished, as the engines are at present working non-condensing, but when the work is finished completely they will work condensing, and he thinks it clearly proved that the use of the accumulators is a great advantage for street-car service.

E. R. D.

The Useful Braking-Effect of Electric-Car Motors.

By LUDWIG BAUMGARDT.

(Elektrotechnische Zeitschrift, 1894, p. 489.)

In this Paper an attempt is made to show theoretically what results may be expected when the electric-motors on a tramcar or electric-locomotive are caused to act as generators of current in descending inclines, and so restore energy to the line in part recompense for that consumed in climbing the grade. The first part of the article consists of an examination into a particular line with grades up to 1 in 10. A given weight is assumed for the car under examination, and the speeds on different parts of the road are taken by the Author at 4 metres per second, on the level,

3·75 metres on an up-grade of 1 in 80, 3·5 metres on 1 in 40, 3 metres on 1 in 20, 2·5 metres on 1 in 13·3, and 2 metres on 1 in 10. Similarly the speeds on falling grades are taken at 4·12 metres on 1 in 10, 4·092 metres on 1 in 13·3, 4·064 metres on 1 in 20, 4·037 metres on 1 in 40, 4·024 metres on 1 in 80, and 4 metres on the level. A loss of not more than 3 per cent. is assumed in the circuit and motor, with a drop in potential of 2·5 per cent.; the working electromotive force is 500 volts, and the traction coefficient 25 lbs. The motor current when ascending the steep grade is 46·5 amperes. From these data, the Author proceeds to calculate the ampere-hours per kilometre or other unit of line, received from and given back to the conductor; thus for the maximum grade of 1 in 10, 6·73 ampere-hours per kilometre are taken from the conductor in ascending, whilst 2·93 ampere-hours are given back in the descent—a proportion of 46 per cent. Over the whole line the average result is only 31 per cent. The following Table shows the consumption and yield in each instance :—

—	Ampere-Hours per Kilometre Consumed.	Ampere-Hours per Kilometre Returned.
Horizontal . .	0·764	..
Up 1 in 80 .	1·840	..
" 1 " 40 .	2·261	..
" 1 " 20 .	3·750	..
" 1 " 13·3.	5·250	..
" 1 " 10 .	6·733	..
Down 1 " 10 .	..	2·933
" 1 " 13·3.	..	2·015
" 1 " 20 .	..	1·250
" 1 " 40 .	..	0·400
" 1 " 80 .	..	..
Horizontal . .	0·764	..
Totals . .	21·362	6·598

Without doubt this result would be less in practice, owing to the effect of curves and bad condition of rails, &c.

The second part of the Paper contains a series of simple mathematical investigations into, and proofs of, the speeds assumed above for the different grades under the conditions laid down.

F. B. L.

The Electric Brake in Practice. By Elmer A. Sperry.

(Transactions of the American Institute of Electrical Engineers, 1894, p. 495.)

The Author points out the great importance of having a powerful brake for street railways, and calls attention to the heavy and increasing damages having to be paid for accidents in the United

States; he asserts that 85 per cent. of such accidents are due to insufficient brake-power.

The problem is different from that in ordinary railway work, for in that case no objection is raised to having expensive apparatus, thoroughly experienced men only are employed, the stops are much fewer and more time is allowed in which to bring the train to a standstill.

The Author is of opinion that if force enough be applied, ample retarding power can be obtained through the intervention of the wheels; and he insists on the importance of coupling the two pairs of wheels together, since, when the brake is applied, most of the weight is thrown on the front wheels, especially when descending a hill, and, if uncoupled, the brake on the hind wheels is practically inoperative.

Experiments were made in which a number of experienced "motor-men" worked a hand-wheel representing an ordinary hand-brake, the pull exerted by them being measured by a dynamometer. Thirteen men were tried, and the average pull obtained was 131·7 lbs. for a direct pull with the right hand; 224 lbs. when both hands were used (this, however, could only be maintained for half a second); and 338·2 lbs. when a supreme or "emergency" effort was made. The Author infers that 180 lbs. is the highest average force available, and, with an ordinary arrangement of brakes, this would give a pressure of about 3,840 lbs. to each of the two brake-shoes on a wheel. The coefficient of friction between shoe and wheel under normal conditions was found experimentally to be about 12 per cent., and hence the retarding effect would be 460 lbs., whereas three times this value might be attained if sufficient force were available on the shoes.

With the electric brake advocated by the Author, all parts normally free to move can do so, thus avoiding jumping the track and straining the framework; the wear on the journals is diminished; lastly, the greatest braking takes place at the highest speed when it is most wanted, the reverse occurring with ordinary brakes. The Author has experimented since 1882, and put the first practical apparatus in operation five years ago; this has been constantly modified, and during the last eighteen months a good many cars have been fitted, one of them running over 70,000 miles and hauling a "trailer" 48,000 miles.

The danger of using the ordinary supply of current for braking purposes is pointed out, viz., its liability to interruption from various causes; in the Author's system the current is furnished by the destruction of the momentum of the car, the motors being employed as generators. This current may be used to apply the brake-shoes, may arrest the car direct by magnetic adhesion, or may be employed to generate Foucault currents in a moving metallic mass. The residual magnetism of the motor is found very useful at low speeds; the current generated was found to persist after the motor was at rest for as much as a second, on account of the self-induction of the circuit; this current is found of great utility

in holding the car at rest on a gradient. The phenomenon has also the effect of enabling the car to be started again immediately after stopping, as the rupture of the current is found to suddenly free the brake-magnet. When no brake-magnets are used, and the electric-brake is suddenly applied when descending a gradient, the car is not only brought to rest but the wheels actually started revolving in the opposite direction, the motion lasting as long as one and a half second in some cases. Owing to losses in the motor, the current required to stop a car is considerably less than that necessary to give it its velocity.

Experiment showed that the rise in temperature of the motor, through being used in the manner described, was exceedingly small.

Two forms of magnet are employed; in one a brake-chain is wound up, in the other the axles are directly retarded. One magnet is provided for each axle, and the magnets are mounted on the truck in such a manner that their weight tends to draw them away from the wheels; they are of crescent form, the gap being left to aid the production of Foucault currents and to admit of easy fixing. The face of the brake is lubricated with graphite, and this is said to aid the production of Foucault currents; these currents are said to enormously increase the retarding power, and a table is given in support of the statement.

The ordinary controller is used for regulating the brake, a single lever sufficing for starting the car, stopping it, and varying its speed; arrangements are made to automatically prevent any damage being done should the attendant make an error. In order to test the durability of a controller, the brake was applied 518,700 times, and it is stated that there was no appreciable wear.

The advantages of the brake are enumerated, the more important being, certainty of action, convenience, large power available without drawing on generating station and without cost, saving of wear and tear of wheels and absence of liability to flatten them, silent action.

The Paper is illustrated with diagrams and reproductions of photographs.

C. H. W.

The Depoele Boring-Machine in Hungary. By H. DROLZ.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1894, p. 480.)

At Zsakaróecz, in Upper Hungary, a trial, extending over more than a year of continuous working, has been carried out with the Depoele electric-boring machine, made by the Thomson-Houston Company. In this machine the boring tool, attached to a round iron bar, is put into rapid motion by circulating intermittent currents, both continuous and alternating, through the windings of a solenoid of which the bar forms the core. For this purpose the winding is divided into a centre and two end parts; the latter

receiving the alternating currents cause the pulsating motion; the function of the central part being the magnetising of the core whereby the action of the ends is intensified. Both kinds of current are obtained from the same dynamo by a combination of fixed and rotating brushes in the commutator, the former giving continuous and the latter alternating currents, the number of blows of the tool being the same as that of the rotation of the moving brushes, or about 450 per minute, when the armature makes 1,600 revolutions. The machine is employed in driving an adit level in a spathic iron ore mine, the source of power being a fall of water, with a head of 93 metres, carried in pipes for a distance of 1,180 metres to a turbine giving 4 HP. with a supply of 7 litres per second and 67 metres useful head, which drives by a belt at 1,600 revolutions per minute a Thomson-Houston dynamo giving about 3,300 volt-amperes, at 220 volts tension. Owing to the special character of the work, three separate conductors are required. These are of bright copper wire, two of 6 millimetres diameter serving for the intermittent, and a smaller one of 3 millimetres for the direct current. From the engine-house they are carried on poles 8 metres high for a distance of 427 metres to the mouth of the Johann Gotsch adit, which upper level is followed for 165 metres to a connecting shaft of 7 metres depth to the level below where the machine is at work.

The total length of the conducting-wires was 600 metres in December, 1892, but this distance was increased by the length of level driven in 1893 to 820 metres. The wires are carried on ordinary porcelain insulators to within 20 metres of the machine, where connection is made with a flexible insulated cable. The machine is enclosed in a cylindrical iron case 18 centimetres in diameter and 132 centimetres long; the weight, including the sliding carriers, is 152 kilograms. For use it was originally mounted on an upright pillar, kept in place by hydraulic pressure, with a movable cross-arm bringing it within reach of any part of the level. This arrangement, besides being very heavy, was deficient in stability, and the cross-arm has been removed, the machine being now clamped directly to the pillar, the weight of the new clamp with that of the pillar being 180 kilograms. From fifteen to twenty minutes are required to set up the machine for use. The borers are of steel with cross cutting-edges from 36 to 24 millimetres broad. When, however, the rock is uniform in character, plain chisel-borers are used.

The full length of stroke is 9 centimetres, which is shortened by obstacles in boring; these, if only small, are easily overcome by the machine by an increase of current proportional to the diminished pressure. It is not, however, safe to allow the current to exceed 25 amperes, to avoid the risk of undue heating and the chance of burning the coils. Under the ordinary condition of working the machine becomes heated to about 60° C. in three hours, but without causing a perceptible diminution in its working power. The condition of the machine can, however, be more

exactly determined by the indicators of the meters on the switch-board than in the mine itself, and for better control telephonic communication is established between the machine and the engine-house. The machine does not appear to be easily affected by external causes, the outer covering being sufficiently close to prevent the influx of water, which may cause short-circuiting in the winding. No damage was observed during two months when the third was so wet that the miners required waterproof clothing while at work. As a matter of precaution, however, when laid off for a few days, it should not be allowed to remain in the damp air of the mine.

Owing to the pulsating character of the work, the power required by the machine is not easily determined. With 220 volts and 20 amperes indicated, the effect corresponds to 2·8 HP., or a duty of about 70 per cent. For continuous working, however, it is preferable to use less power, the most advantageous result being obtained with 15 amperes at 195 to 200 volts, or about 2 HP., when the borer makes 420 strokes per minute.

The ground bored through has been spathic ore, a light-green schist in the veinstuff, and a hard dark-green schist in the hanging wall. The best work done in ten minutes' actual boring was, in the spathic ore 90 centimetres, in the light schist 120 centimetres, and in the dark green 45 centimetres. These results were, however, only obtained when the ground was free from inclusions of quartz, or under the most favourable conditions. In compact quartzite the depth was reduced to 12 centimetres. The average results obtained over longer periods are given in the following Table:—

Period.	Nature of Ground.	No. of Bore-holes.	Total Depth.	Work per Ten Minutes.	
				Boring Time.	Total Time.
1893.			Metres.	Centi-metres.	Centi-metres.
20 Feb. to 20 Apr.	Spathic ore . .	560	412·02	43·08	27·47
29 Apr. to 29 Sept.	Light green schist	1,598	1,319·02	39·40	28·20
29 Sept. to 30 Dec.	Dark green schist	1,222	1,058·70	28·00	21·46

The bore-holes usually range from 80 to 120 centimetres in depth, shorter ones being only used in dressing up the section of the level. The maximum has not exceeded 150 centimetres, but greater depths are within the power of the machine.

The apparent contradiction in the last two columns, which shows that the loss of time was proportionally less with harder than with easier ground, is explained by the circumstance that the miners were at first entirely ignorant of the manipulation of boring-machines; but with the knowledge acquired by continued use, the

time required for changing and setting up the machine has been continually reduced.

As a means of comparison with machines driven by compressed air, the depths bored with the Duisburg machine in the Mansfeld mines are given. These varied in ten minutes, the average time required for boring one hole, from 23·2 centimetres in the bituminous copper schist to 24·5 centimetres in red sandstone, and 29·2 centimetres in dolomite and gypsum. From these figures it appears that the electric machine is equally efficient with the systems previously in use.

As regards the working cost no exact figures can be given as yet. The chief element of wear is the destruction of the coils through loss of insulation in the wires. It was at first considered that, apart from accidents due to gross carelessness, from 500 to 700 holes might be bored without requiring any renewals. The results of the first half of 1894 have, however, given much more favourable results: with two machines in alternate use, 2,461 holes of a total length of 2,203 metres were bored without any accidents; the machines being in the same condition as they were in September, 1893, since which date they have bored 4,094 holes.

H. B.

An Electrolytic Plant at Månsbo, Sweden. By R. Dahlander.

(Elektrotechnische Zeitschrift, 1894, p. 495.)

In the town of Månsbo (in the province of Dalecarlia) are large chemical works, where chlorine compounds are manufactured, and the Author of this article describes in it the installation for generating electric energy employed to split up the raw material electrolytically. The power-station is operated by means of eight turbines, each of 220 HP., deriving their water-supply from an adjacent fall, which has a total estimated capacity of 4,000 HP. The turbine spindles are fixed horizontally, each being coupled directly to one of the dynamo generators which run at 260 revolutions per minute. Each dynamo is normally operated quite independently of the others, a separate switchboard and distributing system being provided for each; but any two adjacent switchboards can be connected on emergency so as to supply either or both circuits from either generator. The dynamos are of the six-pole drum-wound type, each giving an output of 1,200 amperes at 115 volts; this load they may be called upon to bear continuously night and day, with occasional overloads for a short time. To ensure sparkless collection at the brushes, and easily-regulated machines, the armature reaction is reduced to a minimum: first, by making the magnetic-field of comparatively great strength; secondly, by designing the pole-pieces so as to give a somewhat increased resistance to the armature lines of force; and, lastly, by the use of an extra winding on the method perfected by Sayers.

In ordinary working an efficiency of 95 per cent. is obtained with these machines.

One illustration is given to show the interior of the dynamo-room, and there is also a diagram representing the arrangement of coils in the armature, with connections to the ordinary commutator, and the additional Sayers winding.

F. B. L.

The Corrosion of Iron Pipes by the Action of Electric-Railway Currents. By Prof. D. C. Jackson.

(Journal of the Association of Engineering Societies, Philadelphia, 1894, p. 509.)

Electric-railway return-currents having been observed to occasion corrosion of adjoining water- and gas-pipes, the Author proposes in this Paper to examine the extent to which this has actually occurred in various towns; to determine what chemical action really takes place under the conditions met with in those towns; and to indicate the best methods of avoiding the difficulty or danger arising from it.

At Boston, about two years ago, it occurred to the engineers of the West End Electric Street-railway to connect the reinforcing wire, laid between the tracks, to the water-pipes, but soon found that the supplementary wire was destroyed in several places. To remedy this, they reversed the polarity of their generators, sending the current out through the rails and back through the overhead trolley wire; but this change was followed by disastrous results. The current, pumped through the rails, took to the water-pipes and to the lead cable-coverings, following the law of divided currents, and, leaving them at many points along the line, caused serious corrosion at these places. The direction of the current was therefore again reversed, but so great a current flowed along the water-pipes that, at a joint where oakum was used for calking, it was sufficient to set fire to the oakum. The loss of pressure on the return circuit was found to be from 25 to 100 volts, or from 5 to 20 per cent. of the total pressure. The water-pipes having then been experimentally connected with the negative pole of the dynamo, a new danger occurred, for the difference of potential between the gas-pipes and the water-pipes caused a marked electrolytic effect on the former. It was then proposed to connect the gas- and the water-pipes together in all parts of the city in order to arrest the action, and this gave fair results, but the expense to the city and to the company was great, and finally far from satisfactory to either party.

In Brooklyn, where the same trouble arose, it has become very serious owing to the growth of the electric railways in that city, and the Board of Commissioners of Electric Subways of Brooklyn reported in 1893 that the discoveries of corrosion had been numerous enough to justify the belief that all kinds of buried

pipes are being eaten away in many places. As an example, they mention that a certain iron service-pipe, buried at a depth of 4 feet below the track, had been completely perforated in a month.

At Milwaukee the electrical engineer to the Street-railway Company reported in December 1893 that, at 200 feet from the power-house, a 6-inch water-main was so badly corroded, after the electric railway had been at work four years, as to render it entirely useless, and when taken out of the ground it was so soft in some places that a cane could easily be poked through it. The corrosion was arrested at Milwaukee by making numerous low-pressure connections between the pipes and the rails, thus keeping the two at the same potential, and by connecting both pipes and rails at the power-station to the negative pole of the generator. As much as 28 per cent. of the total output is now found to be returned by means of the pipes, and this plan has been working satisfactorily for more than a year.

At Chicago the destructive effects were reported on by Professor Barrett in June 1893, and seem to be entirely similar to those of the above-mentioned cities. Professor Barrett's report mentions some experimental work in which a current of 0·3 ampere, continued for three weeks, was most destructive to a lead telephone cable, while another, buried in the same soil, which was not subjected to the action of the current, was unaffected.

In Zanesville (Ohio) a 4-inch cast-iron water-pipe was completely perforated in two years, and the same difficulties have been experienced at Columbus (Ohio), Hamilton (Ontario), Indianapolis, Philadelphia, Los Angeles (California), and many other cities, where considerable electric-railway systems are in operation. In every case the corrosion has exhibited the same general features. The iron pipes are usually "pitted" in many places.

It is now practically agreed that the reason for the extraordinary corrosion is to be found in the imperfect character of the return-circuit of electric railways. When these were first constructed, the rails in connection with the surrounding earth were relied upon to carry all the current back to the generator. It was soon discovered, however, that the current would not confine itself to this path, and that the resistance of the earth was far from being as low as was originally supposed. Bending the rails, cross-bending, supplementary wires, and ground-plates were then tried, but have not answered; and the tendency now is to make the return-circuit of fully as great conductivity as that of the overhead supply circuit, without relying upon any conductivity from the ground. There is little doubt that with a perfect return system, properly connected to systems of underground pipes, electrolytic disturbances will practically disappear in nearly all cities.

Two theories have been put forward to account for the corrosion, (1) that it is simply due to chemical action caused by ammonia, saltpetre, leakage from gas-mains, &c., found in the earth, and (2) that it is the result of electrolytic action.

Now chemical action undoubtedly has much to do with shortening

the life of iron pipes embedded in the earth, but it evidently cannot produce effects of the magnitude noted above. Where chemical action alone is met with, water- and gas-pipes will ordinarily last about twenty years, but the corrosive action referred to has destroyed new pipes in intervals of from a few weeks to half a dozen years, and it has taken place at the points where the electric current left the pipes. This is conclusive proof of electrolytic action, and the only question is whether it occurs (1) by direct electrolysis of iron, or (2) by the electrolysis of chemical compounds which are held in the water of the soil, causing secondary chemical reactions at the electrodes. The latter is believed by the Author to be the true solution of the problem, and this opinion was confirmed by a series of laboratory experiments in which the practical conditions were reproduced as fully as possible. He holds that the iron pipe acts as the positive plate of a cell; the water of the soil with chemical compounds in solution as the electrolytex, and the rail as the kathode or negative pole.

The analysis of street soils almost invariably shows the presence of some soluble salts of ammonia, potash and soda, and experiments were made to determine the effect of these salts in the electrolytic corrosion of iron plates per ampere-hour. Six small cells were run in series with a current varying from 0·2 to 0·04 ampere and a pressure of about 100 volts. The cells contained clean glass sand moistened with water containing the following salts:

Cell.	Salt Solution.	Result after a Run of Fourteen Hours. Loss in Weight of the Anode per Ampere-Hour.
No.		Gramme.
1	Chloride of potassium (KCl) .	1·346
2	Chloride of ammonia (NH_4Cl) .	1·314
3	Chloride of sodium (NaCl) . .	1·299
4	Nitrate of ammonia (NH_4NO_3)	0·921
5	Nitrate of potash (KNO_3) . .	0·887
6	Nitrate of soda ($NaNO_3$) . .	0·729

Other experiments were also made with solutions of chloride of sodium (common salt), and of carbonate of magnesia, and of lime; the loss in these cases was rather less.

It will be seen that the chloride cells exhibit the greater losses, while the nitrate cells show the smaller.

It was noticed during the experiments that all the cells containing a nitrate gave off a gas at the anode, and this on being collected was found to be oxygen. The same cells showed an acid reaction at the anode, and this and the escape of oxygen seemed to be associated. The acid reaction diminished in intensity as the current decreased.

The experiments showed conclusively that in an electrolytic cell with iron electrodes and a soluble salt, or salts of the metals of the alkalies, or alkaline earth, in solution in the electrolytic, the salt is electrolysed by the current and the acid radical attacks the anode, forming an iron salt, while the alkaline metal forms with water a hydroxide at the kathode, liberating hydrogen there. Precisely similar results were obtained when repeating the experiments with street soils; and as all the conditions of these laboratory experiments are practically paralleled in the earth, it is safe to say that similar chemical reactions must go on there. The composition of street soils is more complex than that of the electrolytes used in some of the experiments, but they nevertheless contain the same soluble salts, and the nature and amount of these in the soil exert the most marked influence upon the corrosion.

It is thus seen that only such measures as will stop the electrolytic action of salts in solution in the soil can be relied upon to stop the corrosion of the iron pipes. This is a problem which requires a careful study of the local conditions in each case before it can be satisfactorily solved, but the Author is quite confident that there are very few places where the difficulty cannot be avoided at a comparatively small expense by proper construction and arrangement of the return currents. Alternating currents produce no appreciable electrolysis, and their employment would avoid all difficulty, but their use for driving street-railway motors is not yet an assured success.

Connecting the pipes with the rails by means of heavy cables at points where the former are positive to the latter has hitherto proved the most effective method of prevention. The conductivity of the track circuit must be properly reinforced by feeders, so that an undue drop may not be experienced in the return conductors, and these track feeders should always be insulated and put on the lines exactly as are overhead feeders, in order to save them from corrosion. Such a connection of pipes and rails has been carried out in Milwaukee, where there are about 125 miles of track and more than 200 cars in daily operation, at a cost of about £1,600, and has apparently succeeded perfectly. At Madison, present indications seem to show that one connection between the rails and the pipe system opposite the power house, costing, all told, about £3, would prevent any serious action. Investigations have shown that when the negative pole of the generator is connected with the trolley, the pipes are positive to the rails over an extended outlying district, and corrosion goes on over a large area; while with the reversed arrangement, the dangerous area is concentrated about the power station. The latter method of connection allows the difficulty to be most easily dealt with by making frequent connections of pipes and rails within the affected area.

O. C. D. R.

Ajax Multiple-Fuse Lightning-Arresters.

(The Electrical Engineer, New York, vol. xviii., 1894, p. 218.)

In circuits having one pole earthed either by accident or design, there is great danger of the dynamo current following the lightning discharge and destroying the points of the arrester spark-gap. In the arrester described a number of very sensitive spark-gaps and fuses are provided, and as one becomes destroyed, another is automatically brought into play. Each gap is made by means of two No. 26 brass wires, each about 3 inches long, so placed that they overlap one another for about an inch, being insulated from each other with one layer of silk on each; the gap is thus equal in length to two thicknesses of silk—about 0·002 inch. The wires are kept in position by small pellets of wax, and the portion of the fuse containing the gap is hermetically sealed in a glass tube to keep it dry and clean. The ends of the wires pass through india-rubber plugs to the back of a corrugated fibrone cover holding the plugs.

Eleven of these fuses are provided and are contained in a porcelain box. In the back of the cover are two metal strips; one is earthed and to it is connected one end of each fuse, while the other which is joined to the line to be protected is U-shaped, and into it the other ends project, but they do not make contact with it. A carbon ball is inserted in the U-shaped strip, putting the top fuse in contact with it. When a discharge takes place and the fuse is destroyed the ball drops, bringing the next fuse into operation. The poor contact made by the ball insures that, if any part of the fuse is burnt, it shall be that end.

In order to increase the chance of protection, a choking coil is inserted in the main circuit to direct the discharge into the apparatus.

The dimensions of the arrester are 7 inches by 4½ inches by 2¼ inches, and when used with a choking coil suitable for 100 amperes is mounted with the coil on a marble slab 7¾ inches by 11 inches by ⅞ inch.

C. H. W.

Preparation of Crystallized Aluminium Carbide.

By Henri Moissan.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxix., 1894, p. 16.)

Aluminium carbide was prepared by placing small boats, made of carbon, containing 15 or 20 grams of aluminium, in the Author's tubular electrical furnace,[1] and heating them for five or six minutes with a current of 300 amperes at 65 volts. During the

[1] Comptes Rendus, vol. cxvii., p. 679.

operation, and while the furnace is cooling, a stream of hydrogen passes through the apparatus. The new substance is of a pale yellow colour, crystalline, and transparent. Some of the crystals were hexagonal, and 5 or 6 millimetres in diameter. The specific gravity was 2·36. Aluminium carbide is decomposed at a red heat by chlorine, with separation of amorphous carbon. Oxygen attacks it only superficially, owing to the formation of a protecting coat of oxide. Sulphur under similar circumstances acts very rapidly upon it. The most characteristic reaction is that with water, which decomposes it slowly at the ordinary temperature of the laboratory, with evolution of marsh gas and formation of aluminium hydrate. This is of importance from a theoretical point of view. The formula of the new body is C_3Al_4.

G. J. B.

New Researches on Chromium. By Henri Moissan.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxix., 1894, p. 185.)

The Author has prepared, with the electrical furnace, 20 kilograms of metallic chromium by a continuous process. The furnace contained an inclined tube of carbon, the upper end of which was fed with a mixture of chromium sesquioxide, and carbon.[1] The cast metal thus obtained was contaminated with considerable quantities of carbon. In attempting to remove this by heating with the sesquioxide, it was found that the resulting chromium became saturated with oxygen, and was in fact "burnt metal." The refining was therefore effected by melting a quantity of cast chromium with lime. Calcium combines readily with the carbon at a sufficiently high temperature, and in this way all but about 1·5 to 1·9 per cent. of carbon was removed. But when the metal is sufficiently pure an inverse action commences, the whole being ultimately converted into a crystalline double oxide of chromium and calcium. A quantity of the refined chromium was placed in a furnace made of quicklime and lined with this double oxide, and after having been melted was found to contain no trace of carbon. The pure metal can be filed and polished with ease. It has a specific gravity of 6·92 at 20° C., is somewhat whiter than iron, and is not magnetic. It is more infusible than crude cast chromium, and has a melting-point above that of platinum. It cannot be melted before the oxy-hydrogen blow-pipe, but in the electric furnace it becomes as mobile as mercury. As much as 10 kilograms could be poured into the mould at a single casting. The presence of 1·5 to 3 per cent. of carbon renders the metal so hard that it can only be worked with a diamond wheel. Two definite compounds of carbon with chromium were examined. The first corresponds to the formula $C_2\,Cr_3$. It is crystalline, and

[1] Comptes Rendus, vol. cxvii., p. 679

hard enough to scratch quartz and topaz, but not corundum. The second has the formula $C\,Cr_4$. It is not so hard, and only scratches quartz with difficulty. It may be prepared by heating together chromium and carbon in a wind-furnace. Chromium combines also with silicon, forming crystals which will scratch the ruby, and are unaffected by acids, or by fusion with caustic potash or saltpetre. It forms alloys with aluminium and with copper, which, in the Author's opinion, may be found useful.

G. J. B.

On Manganese Steel. By H. le Chatelier.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxix., 1894, p. 272.)

Ordinary manganese-steel, containing 13 per cent. of manganese, is non-magnetic, or nearly so, but an allotropic modification has been prepared by the inventor which is magnetic. The change is effected by keeping the alloy for several days at a high temperature. The Author has studied the conditions of this phenomenon. He finds that the non-magnetic variety is transformed into the magnetic by raising it to a temperature of from 500° C. to 650° C., about 550° C. giving the best results. The time required is usually two hours. On further heating to 800° C. the metal loses its magnetic properties, regaining them at about 500° or 600° C. if allowed to cool very slowly, but remaining non-magnetic if the temperature falls more rapidly past the critical point. Apparently the rate of transformation is slow.

The electrical resistance of the two varieties is different at low temperature, but at or near 740° C. it becomes the same in both cases.

Electrical Resistance of a Wire of Manganese Steel 1 Millimetre[1] long and 1·4 Millimetre diameter.

Temperature.	Magnetic.	Non-Magnetic.
° C.	Ohm.	Ohm.
15	0·88	1·06
90	0·99	1·19
300	1·27	1·44
500	1·50	1·65
635	1·70	
730	1·79	
850	..	1·88
965	1·93	
1,020	1·97	1·97

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[1] Apparently a printer's error for 1 metre. Elsewhere it is stated that a length of 1 metre has a resistance of 1 ohm for a diameter of 1 millimetre.—G. J. B.

The coefficient of expansion is the same in both varieties. The following figures are given :—

EXPANSION OF A ROD OF MANGANESE STEEL 100 MILLIMETRES LONG.

280° C.	500° C.	680° C.	830° C.	900° C.	1,060° C.
0·35 mm.	0·67 mm.	1·05 mm.	1·43 mm.	1·97 mm.	2·09 mm.

Sudden cooling in water produces a permanent linear contraction of 0·4 per cent. G. J. B.

On the Use of Kathode Rays in Studying a Variable Magnetic Field. By ALBERT HESS.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxix., 1894, p. 57.)

The Author proposes to employ kathode rays in studying a variable magnetic field. Lenard has shown that these rays, which can be produced only in a high vacuum, can penetrate thin sheets of metal, and are then propagated with equal facility in any kind of gas, even at moderate pressures. They are affected by a magnet, the amount of the deviation being proportional to the strength of the magnetic field, but independent of the pressure, and of the nature of the gas employed. Finally, kathode rays act photographically on a sensitized plate. The kathode rays are generated in a Geissler tube, furnished at the end opposite the kathode with a linear aperture covered with a thin sheet of aluminium. The magnetic field is arranged so that the deviation may be up and down the slit. A sensitized plate passes across the slit with a known velocity, and the variations of the position of the beam of kathode rays are recorded upon it. To obtain a well-defined tracing it is necessary to enclose the sensitized plate in a metallic case containing, preferably, hydrogen at a low pressure.
G. J. B.

New Researches on the Infra-Red Region of the Solar Spectrum. By — LANGLEY.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxix., 1894, p. 388.)

The Author describes a method of using the bolometer for investigating the infra-red region of the solar spectrum, by means of which results can be obtained in the course of an hour which would have occupied years of constant labour with the micrometer.

The bolometer used is exceedingly narrow, and as thin as possible, so as to respond quickly to any variation in the thermal power of the different portions of the spectrum. Its indications

are not only qualitative but quantitative. The prism of the spectroscope is moved by clockwork, so that the entire length of the spectrum passes slowly across the bolometer. As each dark ray crosses it, the deviation of the galvanometer diminishes almost instantaneously, and then returns to its previous position. Formerly this deviation was read off on a scale by the observer.

The Author now records it photographically by a continuous process. The same train of clockwork which moves the prism drives a sensitive plate vertically across the scale of the galvanometer. Accordingly every movement of the needle is registered automatically. The accuracy of the method is illustrated by its application to the region of the double line of sodium (D_1 and D_2). The two lines are not only separated but the nickel line between them is plainly indicated.

G. J. B.

Electricity considered as a Vortical Movement.

By C. V. Zenger.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxix., 1894, p. 417.)

If the discharge of a Ruhmkorff coil or of a Wimshurst machine is taken under a bell glass, in which are two small test-tubes containing respectively hydrochloric acid and ammonia, vortices are formed in the white fumes of ammonium chloride with which the receiver is filled. These vortices condense into cohering strings of crystals which settle down upon the plate of the apparatus. The experiment indicates that electrical discharges cause a whirling motion in matter occupying the space through which they pass. A spark taken between two triangles of tinfoil on a smoked glass plate, produced a white mark 4 or 5 millimetres wide, down the centre of which a thread of carbon was left intact. Helicoidal curves very close together could be distinguished along the track of the discharge. They were right-handed near one pole, and left-handed near the other.

G. J. B.

On the Resonance of Electrical Undulations.

By Nils Strindberg.

(Archives des Sciences Physiques et Naturelles, Geneva, 1894, p. 129.)

By a series of experiments on electrical undulations Messrs. Sarasin and De la Rive arrived at the conclusion that the value of the internode is constant for a given resonator, whatever be the period of the oscillator, and varies with the dimensions of the resonator even if the oscillator is not changed. According to

Bjerknes, this phenomenon depends upon a special relation between the damping of the oscillator and that of the resonator.

Three cases are possible, viz.:

(1) The damping of the resonator may be small in relation to that of the oscillator, in which case the law of Sarasin and De la Rive holds good.

(2) The damping of the resonator may be equal to that of the oscillator, when the phenomena are complex, the wave-length of each affecting the result to an approximately equal degree.

(3) If the damping of the resonator is sufficiently great in relation to that of the oscillator, the law of Sarasin and De la Rive no longer holds.

The value of the internode is constant for a given oscillator, whatever be the resonator, and varies with the dimensions of the oscillator. In this case the wave-lengths observed will agree with those found by other methods in which resonators are not used.

Hitherto the first case alone has been observed experimentally. The Author's researches go to prove the remainder of the theory. The arrangement of the experiment is similar to that described by Blondlot.[1] The oscillator is circular, and furnished with disks the distance between which can be varied. The conducting wire makes a single turn around the primary circle at a distance of 5 centimetres, and its two ends are carried parallel to each other to a distance of 30 metres, where they are joined together. The resonator rests by an insulating support upon these wires in the region of the nodes. It is very light and has two adjustable disks of aluminium, so that its period may be varied. Wires of copper or iron, of different sizes, are used for the resonator circuit to increase or diminish the damping.

The following results were obtained: Copper wires, 1·16 millimetre diameter and 107 centimetres or 140 centimetres long, gave the phenomena observed by Sarasin and De la Rive. Copper wires 0·10 millimetre, and iron wires 0·50 millimetre and 0·20 millimetre, showed the influence of both resonator and oscillator upon the circuit; and with an iron wire 0·10 millimetre diameter and 140 centimetres long, the divergence from the law of Sarasin and De la Rive was very great, the conditions of the experiment evidently coming under the third category of the theory proposed by Bjerknes.

G. J. B.

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[1] Comptes Rendus, February 8, 1892.

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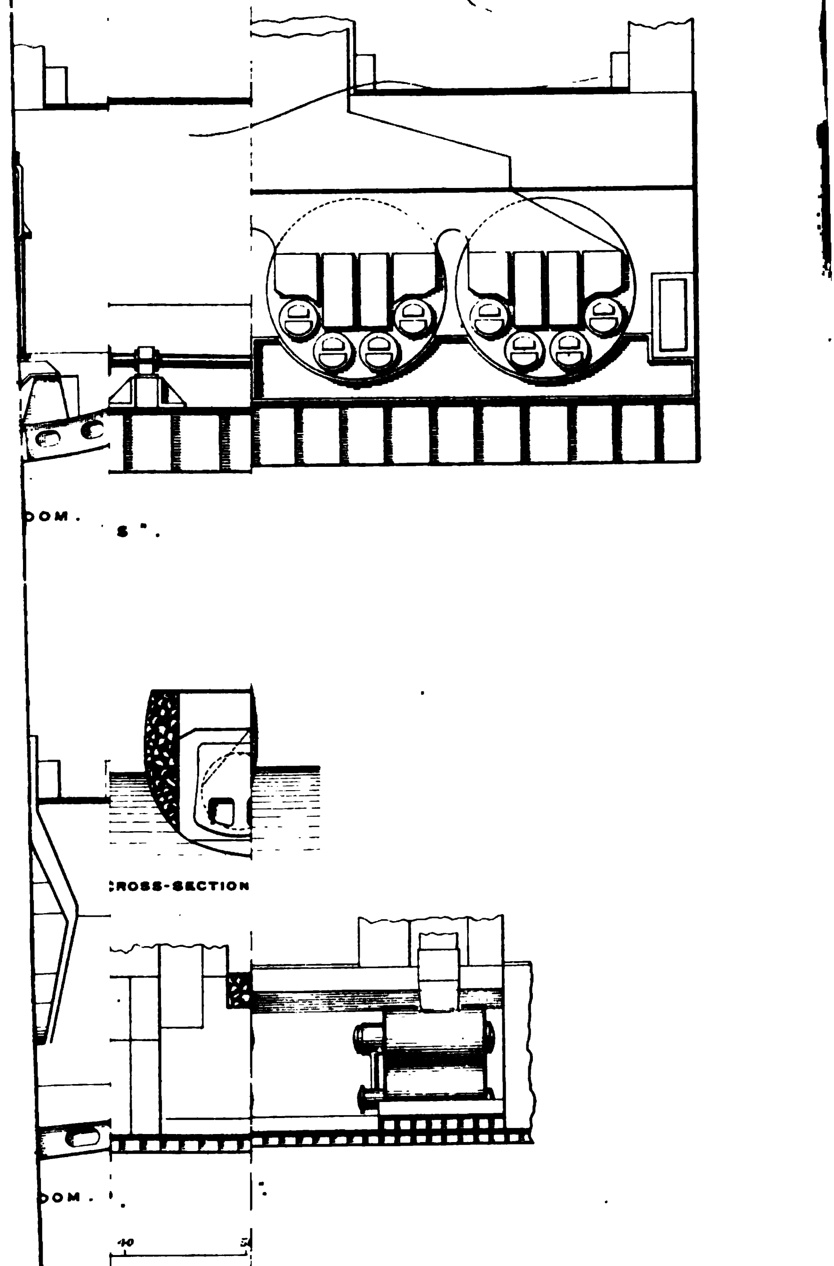

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